Seismic Safety and Safety Element

Santa Barbara County Comprehensive Plan

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Adopted by
Santa Barbara County Board of Supervisors
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Contents

1. Abstract

The Seismic Safety and Safety Element is intended to guide land use planning by providing pertinent data regarding geologic, soil, seismic, fire and flood hazards. Although development in Santa Barbara County dates back to the establishment of the Santa Barbara Mission in 1786, and there has been substantial growth in more recent years, much of the County remains rural and undeveloped. It is therefore appropriate to consider these hazards now in planning for future development.

Santa Barbara County encompasses a wide diversity of terrain and geologic formations and features. It includes mountain ranges such as the Santa Ynez and San Rafael; major rivers such as the Cuyama, Santa Ynez and Santa Maria; extensive lowlands in the Santa Maria, Lompoc, Carpinteria and Goleta areas; and four channel islands.

The County is underlain by up to 35,000 feet of marine sedimentary rocks of late Mesozoic and Cenozoic ages. The sedimentary rocks are diverse, but are dominated by great thicknesses of sandstone and shale with lesser amounts of conglomerate, alluvial fan deposits, dune sand, and diatomite. Outcrops of igneous rocks are limited, except on the Channel Islands. The Rincon and Monterey Formations are two of the weakest and most troublesome formations in the County. They are located primarily in the Santa Ynez Mountains. The geologic units are shown on the geologic maps for the four study areas.

Faults are numerous in the County, several of which are considered major. The main faults have been named, and are shown on the Geologic and Seismic-Tectonic Maps. In the coastal zone, the main faults generally trend east-west; in the northern part of the County, they are predominantly northwest-southeast.

Most of the hills and mountains are folded to some degree. The topography sometimes reflects this structure and sometimes has been substantially modified by erosion.

Earthquakes are not strangers to the County, with strong shaking and major damage resulting from earthquakes occurring in 1769, 1812, 1852, 1857, 1872, 1893, 1902, 1917, 1925, 1926, and 1952. This means that a damaging quake has occurred on the average of every fifteen to twenty years.

Earthquakes are caused by movement along faults, which are surfaces between blocks of the earth's crust. In California, experience has shown that movement during historic times has nearly always taken place along pre-existing faults. Only a very few existing faults are considered to be active or potentially active. The more recently a fault has moved, the more likely it is that it may move again; so active faults have been defined as those which have moved during geologically recent time (approximately the last 11,000 years).

This study considers nine faults to be active: Big Pine, Graveyard - Turkey Trap, Mesa, More Ranch, Nacimiento, Pacifico, Santa Cruz Island, Santa Rosa Island, and Santa Ynez. In addition, the San Andreas fault zone - by far the major fault in California - lies a short distance northeast of the County. Because of its great length and historic activity, it poses a substantial seismic threat to Santa Barbara County even though it is outside the County.

Potentially active faults are of much less concern, but should also be considered. The following eight faults fall into this category: Arroyo Parida, Bradley Canyon, Carpinteria, Goleta, Mission Ridge, Red Mountain, Rincon Creek, and San Jose.

Ground rupture along a fault tract can destroy any structure astride or immediately adjacent to the fault. Therefore, it has been recommended that buildings not be constructed on faults considered to have a significant chance of movement in the next one hundred years. However, much more damage is caused by the resulting earthquake shockwaves. In addition to the major directly damaging effect on buildings, seismic shock can induce - or aggravate - many other potentially disastrous problems such as tsunamis (seismic sea waves, frequently erroneously referred to as "tidal waves"), landslides, settlement, and liquefaction. The intensity of shock waves in bedrock at any given point is largely a function of the magnitude of an earthquake and the distance to its focus. On this basis, the County was divided into zones of relative seismic hazard, as shown on the Seismic - Tectonic Map. Detailed data on local conditions would permit refinement of these "seismic zones," but examination of local conditions was beyond the scope of this study.

Although seismic hazards were the main focus of the study, other soil and geologic problems exist which should be considered - to varying degrees - in land use planning, and, subsequently, in reviewing the design of specific projects. These problems include landslides, expansive soils, soil creep, compressible and collapsible soils, high groundwater, erosion,

and subsidence. Based on available data, areas were classified as having low, moderate, or high susceptibility to each problem, except that fault displacement was considered separately, and erosion and subsidence were not rated. The degree of uncertainty in these designations was also indicated.

In order to avoid having to consider each problem independently in land use planning, a composite number called a Geologic Problem Index (GPI) was devised. The GPI was obtained by multiplying each problem rating number for a given area by a weighting factor and summing the results. Different weighting factors were used for each problem, depending on their relative importance.

The Grading and Building Codes of Santa Barbara County are considered generally satisfactory with respect to geologic hazards, but some amendments are recommended. An adequate investigation of each specific site to be developed is imperative where the possibility of soil or geologic problems exist.

Residents of Santa Barbara County are well aware of the fire hazard problem and the destruction that uncontrolled wildfires can cause. However, sensitive land use planning and effective development regulations can go a long way toward reducing fire hazard.

One critical issue that the County faces is how much development to permit in areas of extreme fire hazard. Short of a case-by-case analysis of local conditions in relation to present and proposed fire prevention and control practices, no definitive rules on overall density in fire hazard areas can be set. Instead, all development activities within areas of high or extreme fire hazard should be closely regulated. In the Subdivision Ordinance, the County already requires that special procedures be followed in fire hazard areas. A requirement that all development proposals be accompanied by a plan to show what the developer intends to do to minimize fire hazard would provide the County with the information necessary for evaluation. In some areas, it may be necessary to prohibit development, but, in others, development could be permitted if adequate control measures were implemented. The cumulative impacts of development in fire hazard areas should be examined, as well as the individual impacts.

A secondary issue is what kinds of controls should be instituted to reduce fire hazard. Research foresters in the U.S. Forest Service have put forth the concept of controlled burns as an improved technique for fire management in chaparral areas. The objective of this type of program is to achieve an acceptable and realistic level of fire occurrence and fire size based on ecological, social, and economic considerations. If this system were to be implemented in Santa Barbara County, the long term trend toward fewer, larger fires might be reversed. County residents would have to tolerate more fires burning over 100 acres, but far fewer fires burning over 5,000 acres. The

chaparral ecosystem would be maintained, and watershed and flood damage possibly could be reduced. A study should be undertaken by the County jointly with responsible federal and State agencies to determine whether this procedure would be viable and should be implemented locally.

One of the most important flood control issues facing the County concerns regulation of development in areas prone to flooding. For current flood control programs to be effective, it is important that the flood-carrying capacity of streams and floodway areas not be impaired. Of related importance, obviously, are the fire hazard issues previously discussed. Because of their interrelationship, decisions on flood control improvements should not be made independently of decisions on fire prevention and control programs, and on land use in areas of high and extreme fire hazard.

Another policy issue related to flood control involves the multiple use of buffer zones alongside flood channels. Setbacks from these channels can provide public access for maintenance of the channels as well as reducing the threat to structures from bank erosion. Preservation of streamside natural communities is another advantage. Setbacks also can be used for recreational trails. However, the privacy and security of neighboring property owners may be threatened.

The U.S. Department of Housing and Urban Development, in cooperation with the County Flood Control and Water Conservation District, is mapping flood hazard areas in the County. When finalized (scheduled for December 1978) these maps will form the basis for flood plain management required under the National Flood Insurance Program, and will be used to establish flood insurance rates. The Federal Flood Plain Management Regulations provide that "flood insurance shall not be sold or renewed under the program within a community, unless the community has adopted adequate flood plain management regulations consistent with federal criteria." The Seismic Safety and Safety Element recommends implementation of flood plain zoning or other similar measures.

The element raised a number of questions deserving further investigation. More geologic data are needed, particularly with regard to seismic - tectonic mapping. Problems along the coast, such as shoreline regression, liquefaction potential and tsunami risk, need additional study. As new information becomes available, it will be incorporated as addenda to this element. An update of the Seismic Safety and Safety Element should include a study of emergency services planning in the County.

A bibliography of the general geology and seismicity of Santa Barbara County was compiled and a list of references cited in the text was prepared. A glossary of selected geological and seismological terms commonly used in practice and in the text also is included.

II. Introduction

STUDY PURPOSE AND ORGANIZATION

Objectives

The purpose of this study was to obtain data concerning geology, soils, seismicity, and fire and flood hazards of Santa Barbara County, and to provide recommendations and criteria to aid in land use planning in order to ensure that future development will be compatible with the environment.

The California Government Code, Sections 65302 (f) and (i), requires a Seismic Safety Element and Safety Element as part of all city and county general plans. The State General Plan Guidelines suggest consolidation of similar elements where possible, in order to avoid "excessive duplication and cross references to the similar or identical subjects contained in the separate elements."* With regard to the Seismic Safety and Safety Elements, the Guidelines state:

> The seismic safety element contributes information on the comparative safety of using lands for various purposes, types of structures, and occupancies. It provides primary policy inputs to the land use, housing, open space, circulation and safety elements.
>
> Because of the close relationship (of the seismic safety element) with the safety element the local planning agency may wish to prepare these two elements simultaneously or combine the two elements into a single document.**

Participating Consultants

The investigation was a team effort headed by Livingston and Associates and Moore and Taber. The team consisted of the firms and individuals listed below. The portions of the study for which each participant was primarily responsible are noted.

Although not a part of the team organized by, and responsible to Moore and Taber, Environmental Systems Research Institute (ESRI)

*Council on Intergovernmental Relations, September 1973, p. III-7.

**p. IV-27.

played a vital role by handling all of the computer work involved in the Geologic Problems and Geologic Problems Index.

Organization	Portion of Study
Moore and Taber Anaheim Woodland Hills	General coordination and review of geologic/seismic portions of study. Preparation of all sections of report not specifically listed for other team members
California Earth Science Corp. Santa Monica	Preparation of section on faults and seismic hazards and bibliography
Lindvall-Richter and Associates Los Angeles	Preparation of seismic history, tsunamis, and review of seismic hazard evaluation
Robert M. Norris, Ph.D. and Robert W. Webb, Ph.D. University of Calif. Santa Barbara	Preparation of geography and geology description, coastline erosion, and geologic interest areas
Livingston and Associates San Francisco	Preparation of Fire Hazard chapter
Bookman-Edmonston Engineering, Inc. assisted by County Flood Control Engineer	Preparation of Flood Control chapter

Acknowledgments

We wish to acknowledge the invaluable assistance of our consultants, particularly California Earth Science Corporation whose efforts were extensive and beyond the originally anticipated scope.

We are also grateful to Wendell Nichols and Ray Coudray, engineering geologists in the County Public Works Department and the staff of the County Planning Department for their assistance including making their files and aerial photographs available. Dr. Jack Estes of the University of California, Santa Barbara and Mason Hill were most helpful to California Earth Science Corporation.

THE STUDY

Scope

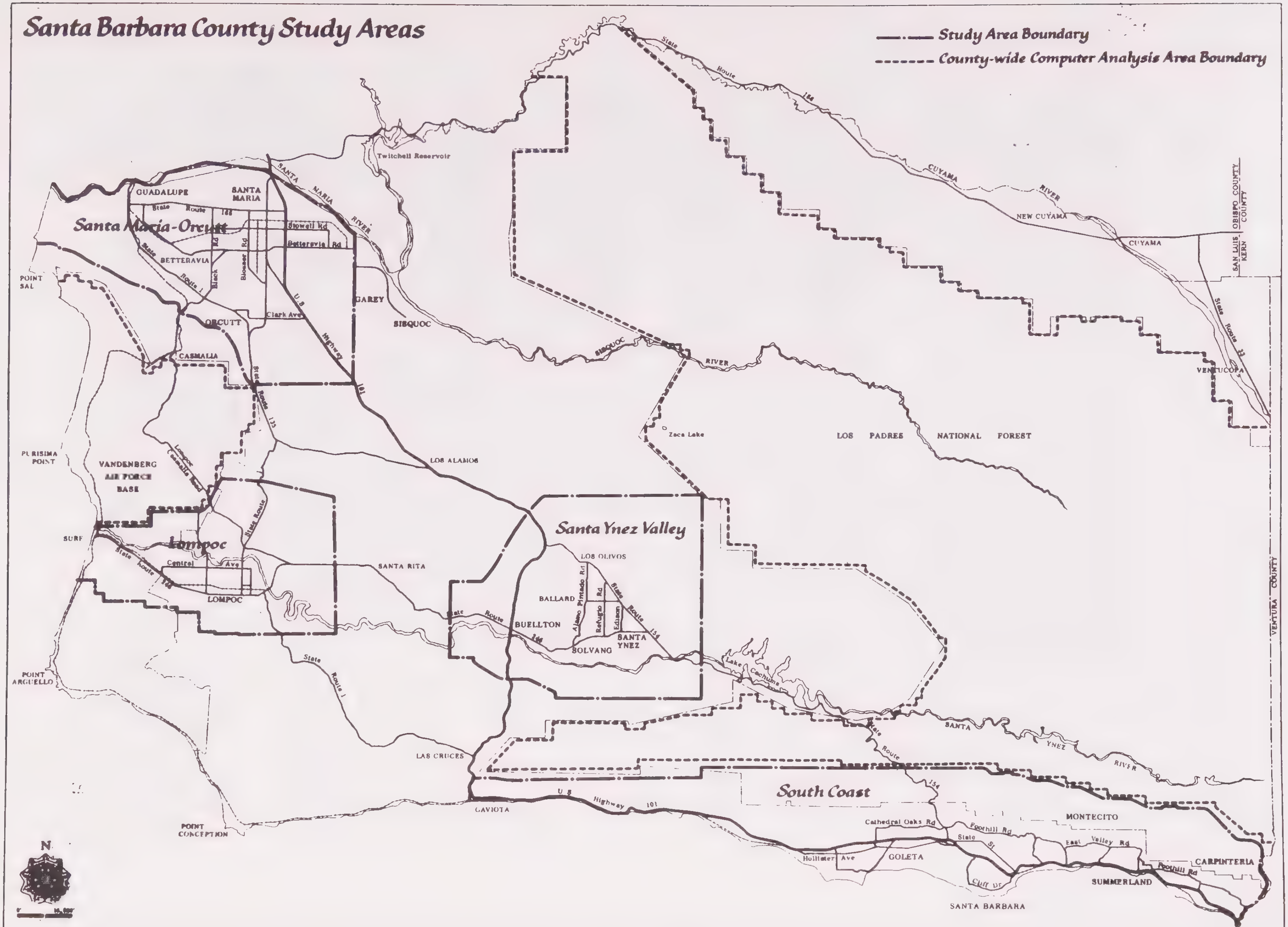
The study consisted primarily of a thorough review of the general geology of Santa Barbara County and its compilation onto base maps, and an investigation of the main geologic and soil problems, with emphasis on those associated with faults and earthquakes. Specific geologic and soil problems that were considered, together with their effect on land use planning, were ground rupture, ground shaking, tsunamis and seiches, soil liquefaction, landslides and slope stability, expansive soils, soil creep, compressible and collapsible soils, high groundwater, erosion and shoreline regression, and subsidence.

Although not considered a soil or geological problem, areas with unique geological features of interest were listed and described so that they could be considered for preservation. Mineral deposits and soil characteristics as applied to agricultural uses are investigated in the Conservation Element.

For purposes of the study, the County was divided into four study areas mainly on the basis of population and future potential development. The study areas consist of the following:

South Coast:	Elongated area along the coast divided into west, central, and east sections, extending from Gaviota Pass to the Ventura County line and from the coast to the approximate crest of the Santa Ynez mountains.
Santa Ynez Valley:	Approximately square area in the Santa Ynez River Valley, extending from the vicinity of Buellton on the west to San Lucas Ranch on the east, north to Los Alamos, and south to and including the foothills of the Santa Ynez mountains south of the Santa Ynez River.
Lompoc:	Roughly rectangular area along the Santa Ynez River, extending from the Pacific Ocean on the west to Santa Rita Valley on the east, north to the approximate crest of the Purisima Hills (but not including Vandenberg Air Force Base), and south to and including the hills south of the Lompoc urban area.
Santa Maria:	Includes the area bounded by the Pacific

Santa Barbara County Study Areas



Ocean on the west. Casmalia and Solomon Hills on the south, Fulger Point - Bradley Canyon on the east, and the Santa Maria River on the north.

Topographic base maps for the county (1" = 8000') and each study area (1" = 2000') were supplied for transfer of geologic and soil data. The geologic and soil problems were studied in a general way on a Countywide basis and in more detail for the four study areas.

The study included a thorough review of published technical reports and geologic maps, a review of most pertinent unpublished reports, and discussions with many public officials and personnel with special technical or geologic expertise.

A comprehensive up-to-date bibliography of all available published data, including masters and Ph.D. theses of the geology and seismicity of Santa Barbara County was compiled. A list of all references cited in the text of the report, in addition to the bibliography, also was prepared.

An extensive study of stereographic aerial photographs was made, primarily to detect ancient landslides. While most of the work involved collecting and evaluating existing data, this portion of the study added a substantial amount of new information.

Inspection trips were made to familiarize consultant staff with some of the areas of the County and to check specific points in question.

Limitations

Every attempt was made to provide a thorough study within the limitations of time and funding, and it is believed that this goal has been achieved. Nevertheless, the inherent limitations of such a study must be recognized. Although specific limitations are described elsewhere in this report - particularly with respect to the present limited state of knowledge of seismic hazards - this subject must be emphasized. The large area covered by the study, the scale at which the work was done, and the limited data available in many areas means that the results are not infallible, particularly with respect to small areas.

The study is an appropriate early step in planning and should be very useful in this regard, but care must be exercised that it is not taken as the final answer regarding decisions on any specific site. New data developed in specific site investigations - or

new techniques - may supersede the generalized conclusions presented in the report. Also, factors other than geologic conditions may be more critical. Except for ground rupture along a fault, and sometimes massive landslides, the geologic and soil problems normally encountered can usually be solved by appropriate engineering design of structures and grading.

Data Collection

Information was taken from the pertinent published references listed in the accompanying Bibliography. In addition, valuable data - both written and oral - was obtained from the following organizations.

- U. S. Geological Survey
- U. S. Department of Agriculture
  - Soil Conservation Service
- California State Division of Oil and Gas
- County of Santa Barbara
- City of Santa Barbara
- City of Carpinteria
- City of Guadalupe
- City of Lompoc
- City of Santa Maria
- University of California, Santa Barbara
- Santa Barbara City College
- Montecito County Water District
- Various private consulting firms

Geologic Maps

Just as the heart of an architect's efforts are his building plans, so are geologic maps for the geologist. On these he plots his data from field observations, boring logs, aerial photographs, and other sources to portray the geologic structure and history and to make evaluations in terms of geologic problems that might affect the use of the land.

The geologic maps of the four study areas presented with this report are a compilation of geologic data from several sources. No original field work or mapping was done by Moore & Taber during the investigation, although a fairly extensive study of aerial photographs was made to map ancient landslides. Basically, the work by Thomas Dibblee, Jr. (Bulletins 150 and 186) and W. P. Woodring et al (Professional Paper 222) were utilized as the base geologic maps for the urban study areas. At the eastern end of the County in the Carpinteria district, the geology was taken from a Ph.D. thesis by Harold Lian (UCLA, 1952).

Various U. S. Geological Survey Groundwater Supply Papers were also utilized, and where the geology differed substantially from that of Dibblee or Woodring, particularly in regard to faults, these features were shown on the geologic map and their sources noted. This is also true for faults located by private consultants. The area covered by each source map is shown on the legend accompanying each map.

Essentially, these various source maps were spliced together where necessary and enlarged by photographic methods to the required scale. The data were then transferred to the base topographic maps for the four urban study areas (1" = 2000').

A 1" = 8000' reproduction mylar composite geologic map of the County prepared as a part of this study is on file in the County Public Works Department. However, a countywide geologic map was not reproduced as a part of this report because of the cost and the fact that the four California Division of Mines and Geology state map sheets which cover Santa Barbara County are publically available. All of the significant faults are shown on the Countywide Seismic - Tectonic map and geological detail is shown on each of the study area geologic maps.

The geologic compilation shows the major bedrock units, surficial units, faults and folds. Most of the rock units and faults are shown exactly as indicated on the source maps used to compile the geologic and seismic - tectonic maps of the various study areas. Contacts between geologic units and faults on the geologic map do not necessarily match at boundaries between map source areas even by the same author, and they generally were not adjusted during the compilation. Since no original field work was performed by Moore & Taber during the investigation, no significant attempt at reconciliation of the discrepancies was made. Reconciliation and field checking were not possible with the available time and funds allotted.

The various formational and rock units with their symbols, as shown on the geologic maps, are those used on the source geologic maps for the particular area. Where there is a discrepancy because different authors use the same symbols for different rock units, the most reasonable symbol was used. This is the case for example, for the Sisquoc Formation (Tsq) as mapped by Dibblee opposed to Sisquoc mapped by Woodring (Ts). The symbol (Ts) as mapped by Dibblee refers to the Sespe Formation, therefore, Tsq has been used on the maps to represent the Sisquoc Formation and Ts has been used to denote the Sespe Formation.

Seismic - Tectonic maps were prepared for the County and each of the four study areas. These maps show all the known faults and folds obtained from the various source maps and designate the relative degree of activity and the estimated maximum credible and maximum probable earthquake magnitude (where applicable) assigned to each fault. Based on distance from the causative fault and the estimated earthquake magnitude, zones of earthquake intensity were established, and these are also shown on the maps. Areas subject to inundation by tsunamis were also rated and shown on these maps.

Because of photo enlargement, scale differences between individual maps, drafting and transfer techniques, and reproduction methods, possible error in the exact location of formational contacts and faults and folds may be present when compared with or in relation to existing cultural features.

While the transferred and compiled data at the larger map scale (1" = 2000') will prove extremely useful in planning, much of the geologic mapping was performed many years ago and, therefore, needs to be updated with more recent geological detail and cultural features.

Problem Rating Maps

The various soil and geologic problems were evaluated and rated according to the severity of the problem by applying geologic and engineering judgment to available geologic and soils data gathered in the study. The data were transferred to the topographic base maps for the County and study areas to delineate the areal extent and degree of the problem. The data from the base maps were transferred to grid base maps and the ratings for the individual problems were then encoded to produce the various computerized maps. These maps reflect the approximate severity of each problem and its areal extent by means of a series of symbols.

Problems that were rated and delineated on topographic base maps were tsunamis - seiches, earthquake intensity (ground shaking), liquefaction, slope stability, compressible soils, and high groundwater. Expansive soil and soil creep (a function of expansion and slope) were derived directly from data obtained from the Soil Conservation Service maps and slope maps.

In addition to the problem rating - distribution map of each problem, the weighted summation of all of the eight problems was computed to obtain the Geologic Problem Index (GPI). The numerical range of the GPI was then divided into five categories of severity to produce a GPI severity map for the County and

each of the four study areas. A more detailed description of the whole rating system, as well as the criteria used in rating each problem, are given in subsequent sections of the report.

III. General Geography and Geology

INTRODUCTION

Santa Barbara County encompasses a wide diversity of terrain and geologic formations and features. It lies partly in the Transverse Range geomorphic province and partly in the southern Coast Range province. The boundary between these two provinces is usually drawn along the Santa Ynez River. The Transverse Ranges of the County include the Santa Ynez Range, the Santa Barbara Channel offshore, and the Channel Islands. Three of the islands - Santa Cruz, Santa Rosa, and San Miguel - represent the seaward extension of the Santa Monica Mountains. Little Santa Barbara Island, some miles to the southeast, is also included in the County, but is more properly included in the Peninsular Range province of Orange and San Diego counties.

GEOGRAPHY

<u>Topography</u>

Santa Barbara County, westernmost of the Southern California counties, includes 2740 square miles and four channel islands. The County is bounded on the west and south by the Pacific Ocean and on the north and east by San Luis Obispo and Ventura respectively.

Three major east-west trending valleys dominate the northeastern half of the County. The Cuyama River Valley, the Santa Maria Valley and Los Olivos - Los Alamos lowland. The northernmost, the Cuyama River Valley is bounded on the south by the Sierra Madre with elevations ranging from about 400 feet to 5845 feet at Peak Mountain.

The Sisquoc River separates the Sierra Madre from the San Rafael Mountains, whose elevations range from about 3000 feet to 6828 feet at Big Pine Mountain. Other typical peaks are Figueroa Mountain (4528'), Bald Mountain (4042'), and San Rafael Mountain (6593'). These summits and the connecting ridge are known as Hurricane Deck. Relief in the eastern county is considerable, and the topography is generally rugged because of the rapid downcutting of the Cuyama, Sisquoc, and Santa Ynez rivers and their tributaries.

In contrast, the northwestern third of the County is dominated by a series of low hills with separating valleys, some of which are broad and flat. The Santa Maria Valley, on the north, extends about eight miles southward to the Casmalia and Solomon Hills and about twenty miles from the settlement of Sisquoc to the sea. The highest peaks in the Casmalia and Solomon Hills

are Mount Lospe (1840') and Mount Solomon (1340'). All the valleys and intervening ridges in this part of the County have a northwesterly trend.

South of the Casmalia-Solomon Hills lies the Los Clivos - Los Alamos lowland, whose lower portion is called the San Antonio Valley, which crosses Vandenberg Air Force Base to reach the sea. This valley is bounded on the south by the Purisima Hills, whose highest peak is Redrock Mountain (1984'). The narrow Santa Rita Valley separates the Purisima Hills from the Santa Rita Hills to the south. Beyond lies the relatively broad Lompoc Valley, which is drained by the lower Santa Ynez River.

Development

Like most climatically desirable parts of California, Santa Barbara County has been experiencing rapid population growth. The proportion of acreage still readily transferrable from rural to urban use, in which natural geologic hazards are minimal, is limited. Pressure to develop areas subject to substantial geologic hazards or problems is increasing. These hazards must be recognized and considered in the planning and design of projects in such areas.

Moreover, loss of recreational resources is a growing problem. Potential recreational areas near urban centers may be lost unless the wisest long-term planning is implemented and natural preserves are expanded beyond those already designated (such as the less accessible National Forests and Parks). Increasingly, as energy sources are diminished, recreation areas close to population centers will be needed.

Fortunately, the County is not yet so urbanized that planning is in the "too little and too late" category. It is imperative, however, that the sort of poorly-planned urban sprawl seen elsewhere in Southern California be avoided. In too many instances in the past, rapid population growth in California has pushed new urbanized development into geologically unfriendly terrain, where even minimal precautions were not observed because of ignorance of facts that were often readily available. Planning can avoid the areas least feasible for development from a geologic point of view. Thorough geologic and engineering studies, and possibly substantial corrective work, may be required in other areas to provide reasonable assurance of a trouble free environment.

GEOLOGICAL FORMATIONS

The County is underlain mainly by marine sedimentary rocks of late Mesozoic and Cenozoic ages.* Many of these rocks were deposited in a marine environment roughly similar to the margins of the Santa Barbara Channel. Some of the County's prominent rock units, however, seem to have been laid down in marine waters as much as 6000 feet deep, perhaps like the deeper parts of the Gulf of California.

All these bedded sedimentary rocks have been subjected to strong compressional forces producing folds and faults, which are especially evident in the San Rafael and Santa Ynez Mountains and on the offshore islands. The hills and valleys in the northwestern part of the County are chiefly controlled by folding and faults are few. In the Transverse Range section of the County, both folds and faults trend strongly east-west, giving rise to the prominent grain of those ranges. Likewise, in other parts of the County, the trend of both folds and faults is more northwesterly, consistent with the grain of the Coast Range province.

The rock formations exposed in the County are largely of marine sedimentary origin, except on the offshore islands which also include volcanics and basement rock. Total thicknesses of the formations are impressive: more than 25,000 feet in the Santa Ynez Range, up to 35,000 feet in the San Rafael Mountains, and 15,000 feet under the Los Olivos - Los Alamos lowland, to mention only a few.

The sedimentary rocks are diverse, but are dominated by great thicknesses of sandstone and shale with lesser amounts of conglomerate, alluvial fan deposits, and dune sand. Of the more common sedimentary rocks, limestone is the most poorly represented in the County; only a few thin beds occur in the San Rafael and the Santa Ynez Mountains. Some unusual sedimentary rocks are prominent, however, such as the thick diatomites or diatomaceous shales found in the upper Monterey and Sisquoc formations. Thick, light-colored diatomites, whose purity and quantity are as yet unmatched anywhere in the world, are derived from the Sisquoc formation near Lompoc and have been the basis of an important mining industry for many years. (The sequence of sedimentary rocks found in the County is summarized in the columns shown in Figures 1 to 6.)

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* Late Mesozoic - 140 to 70 million years before present;
Cenozoic - 70 million years to the present.

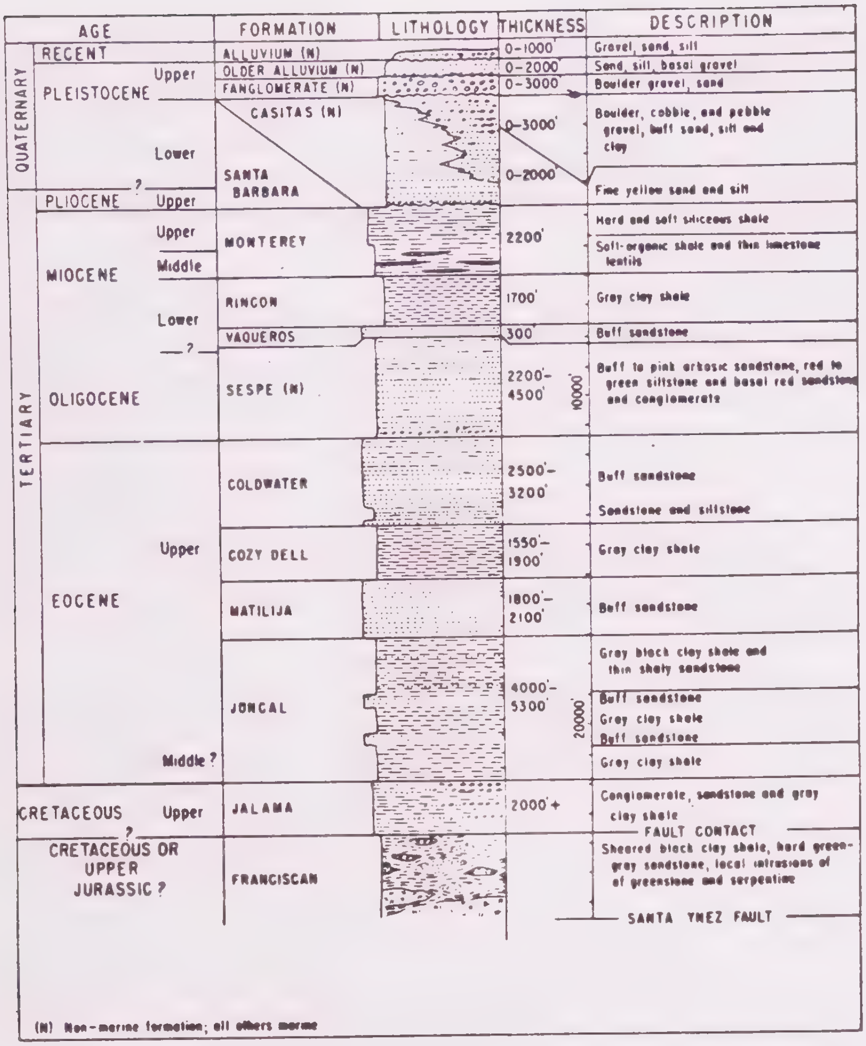

FIGURE 1

SEDIMENTARY ROCK UNITS SOUTH OF SANTA YNEZ FAULT
EAST OF SAN MARCOS PASS

(From T. W. Dibblee: California Division of Mines and Geology, Bulletin 186, 1966)

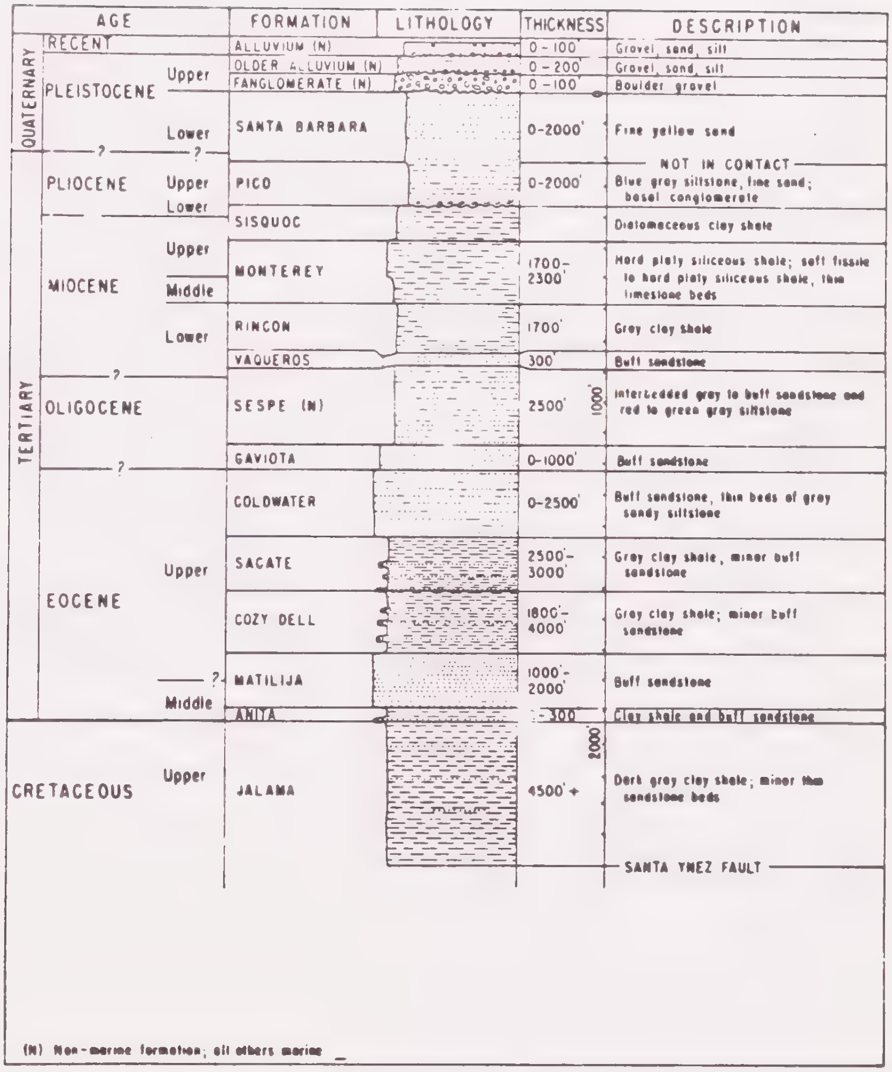

FIGURE 2

SEDIMENTARY ROCK UNITS SOUTH OF SANTA YNEZ FAULT, WEST OF SAN MARCOS PASS

(From T. W. Dibblee: California Division of Mines and Geology, Bulletin 186, 1966)

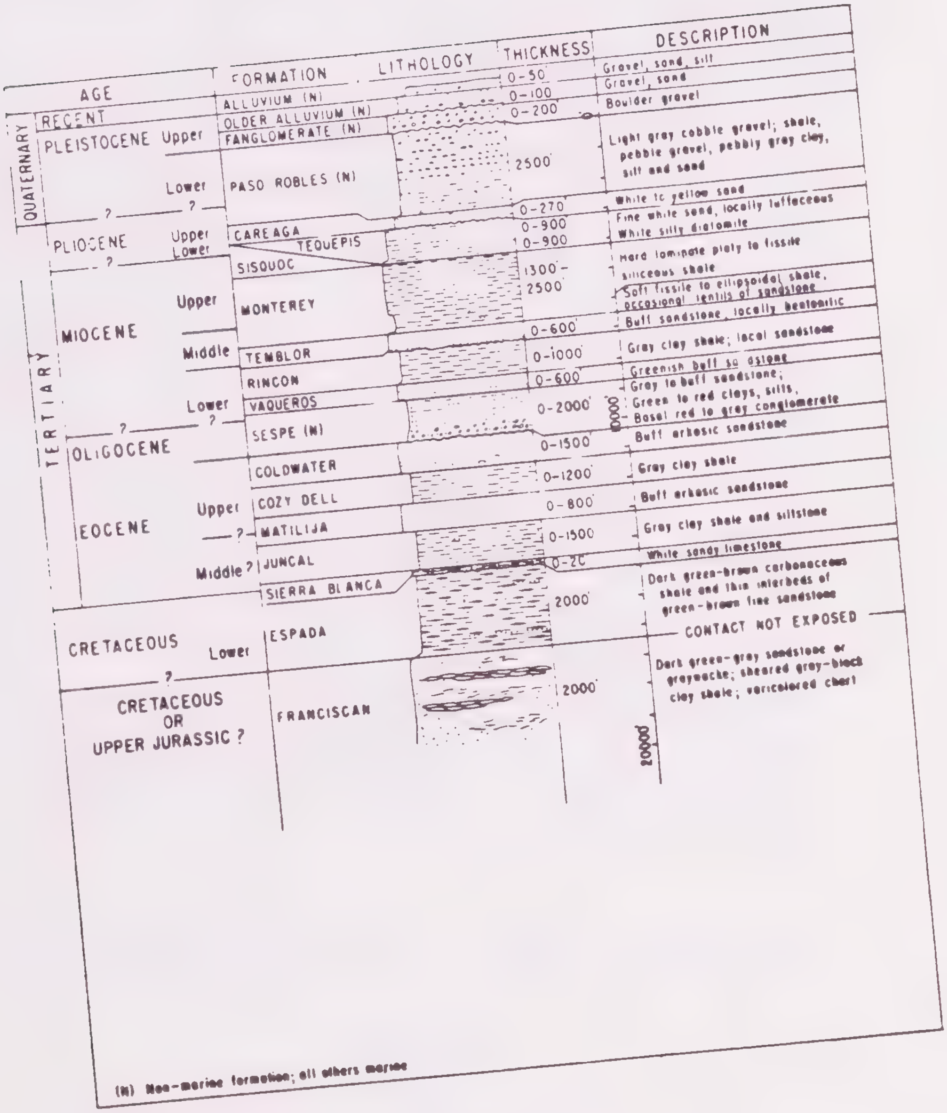

FIGURE 3

SEDIMENTARY ROCK UNITS NORTH OF SANTA YNEZ FAULT

(From T. W. Dibblee: California Division of Mines and Geology, Bulletin 186, 1966)

AGE		FORMATION	LITHOLOGY	THICK	DESCRIPTION
Recent		Alluvium		0-100	Silts and gravels
Pleistocene	upper	Terraces		0-100	Gravels
Pliocene	lower	Sisquoc		3200'+	Diatomaceous siltstone. Clay shale or diatomaceous mudstone. Thin bedded clay shale or laminated diatomite.
?					
Miocene	upper				
	upper / middle	Monterey		1000'-3000'	Porcelaneous and cherty siliceous shales. Organic shales and thin limestones.
	lower	Tranquillon		0-1200'	Rhyolite and basalt lava agglomerate, tuff, bentonite.
		Rincon		0-1700'	Claystone
		Vaqueros		0-900'	Sandstone & conglomerate.
Oligocene		Sespe / Alegria		0-2000'	Pink to buff sandstone and red and green siltstone. Gray to buff marine sandstone.
		Gaviota		1600'±	Fossiliferous buff sandstone and siltstone
Eocene	upper	Sacate		1000'-1500'	Buff sandstone and clay shale.
		Cozy Dell		700'-2000'	Brown clay shale.
		Matilija		0'-2000'	Buff arkosic sandstone.
	middle	Anita		0'-1000'	Dark gray clay shale.
		Sierra Blanca		0-50'	Algal limestone lens
Cretaceous	Upper	Jalama		2200'+	Buff fine-grained sandstone. Gray siltstone. Buff sandstones and gray clay shales.
	middle? and Lower	Espada		4000+ to 6800+	Dark greenish brown carbonaceous shales and thin sandstones. Basal pebbly sandstone.
?					
Jurassic	Upper	Honda		1500'	Dark greenish brown nodular claystone.
		Franciscan		?	Hard green sandstone and black shale. Serpentine intrusions.

FIGURE 4

SEDIMENTARY ROCK UNITS IN WESTERN SANTA BARBARA COUNTY; WESTERN SANTA YNEZ MOUNTAINS

(From T. W. Dibblee: California Division of Mines and Geology, Bulletin 150, 1950)

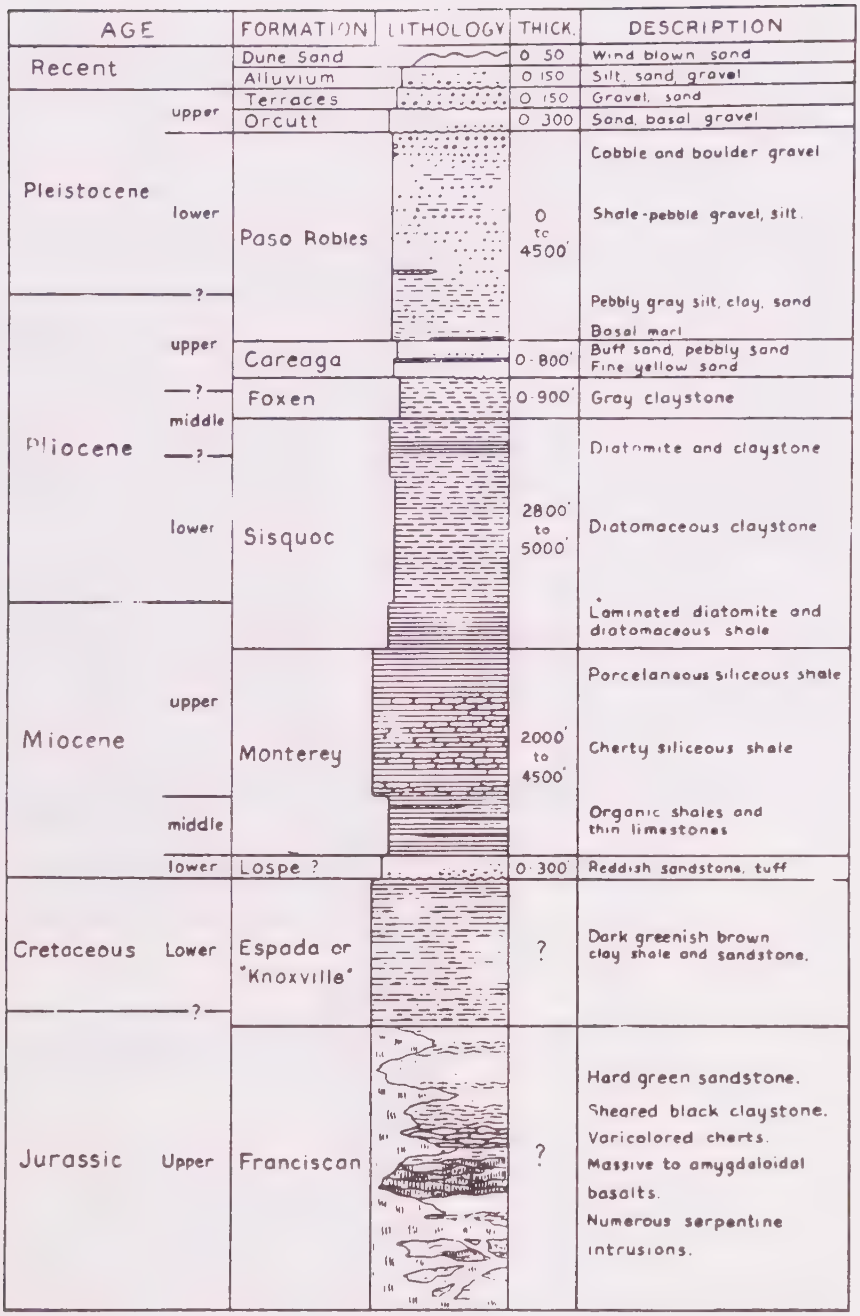

FIGURE 5

SEDIMENTARY ROCK UNITS IN WESTERN SANTA BARBARA COUNTY; SOUTHERN SANTA MARIA BASIN

(From T. W. Dibblee: California Division of Mines and Geology, Bulletin 150, 1950)

Igneous rocks are quantitatively unimportant on the County's mainland and are associated mostly with the Franciscan formation exposed in the San Rafael Mountains, the Casmalia Hills, and at a few places in the Santa Ynez Range. These rocks are of considerable interest as far as California's geologic history is concerned, especially those outcrops near Point Sal in the Casmalia Hills, but apart from the serpentines and small amounts of chromite, they are of little economic interest. Serpentines are metamorphic rocks of greenish, blackish, or grayish color formed by the alteration of earlier volcanic rocks. Where serpentine crops out extensively, as on the slopes of Figueroa Mountain, landslides and unstable ground are ever-present deterrents to land development.

One of the County's most troublesome rock units is the Rincon mudstone, which is exposed in a band on the south face - and locally on the north flank - of the Santa Ynez Mountains from near Point Conception eastward to the County line at Rincon Creek. The Rincon forms grass-covered slopes in the upper foothills, resulting in open country free of chaparral whose smooth, rounded slopes have encouraged development. Unfortunately, this rock readily breaks down into an unstable, heavy, clay soil, which expands when wet and develops deep cracks when dry. It slumps naturally and frequently where slopes occur. These unfavorable characteristics have proved costly and troublesome where houses and roads are built on this rock unit. Where the terrain is flat, structures have been damaged by the constant expansion and shrinkage of the soil; where slopes occur, these effects are augmented by the tendency for soil creep, slumps, and landslides to develop.

To some extent, soils developed on the Monterey Formation share the Rincon's difficulties, although as a rule they are not as severe.

Several other formations have characteristics that can produce special problems. The Fanglomerate or Older Alluvium, which occurs discontinuously in the lower foothills of the Santa Ynez Range, is so excessively bouldery (it contains huge blocks of sandstone, often eight to ten feet across) that any construction can prove extremely costly if excavation is required. The Santa Barbara formation, which occurs in patches on the coastal hills and in the lower foothills from Carpinteria to Goleta, is so soft and weakly cemented that it is rapidly gullied and washed wherever the protective vegetative cover is removed. Steep slopes are especially hazardous unless great care is taken to maintain the vegetative cover intact.

In the northern part of the County, the old dune sands, which extend well into the eastern Santa Maria Valley and Santa Rita Valley behave erosionally much as the Santa Barbara Formation does. The dunes are naturally covered by short grass and other annuals that effectively stabilize the sand. Where this cover has been removed, however, the soft and uncemented sands are quickly picked up by wind, and little scars become larger as sand is blown away. This sand is somewhat subject to gullying as well, but slopes are generally minimal so that wind erosion is usually the most serious problem.

Volcanic rocks are uncommon on the mainland. Some basalts and rhyolites do occur in the western Santa Ynez Range near Mount Tranquillon, but by far the larger portion of the volcanics is found on offshore islands, particularly on Santa Cruz. Much of the north coast of Santa Cruz, from Prisoners Harbor to the western tip, is composed of a thick mass of basaltic and andesitic flows, some of which were once quarried to build the Santa Barbara breakwater. Basaltic rocks occur on both Santa Rosa and San Miguel islands, but not as abundantly as on Santa Cruz. Much of the western half of the south side of Santa Cruz is composed of volcanic rocks also, but these are tuffs, agglomerates, and fragmental volcanics rather than flows. Santa Barbara Island is composed entirely of basaltic lavas.

GEOLOGIC STRUCTURE

Faulting

A general description of faulting is given here. For a more detailed discussion of faults and their relationship to seismic hazards see sections on "Regional Geologic Structure" and "Description of Individual Faults." Faults are numerous in the County and include several major ones. The main faults have been named, and are shown on the Geologic and Seismic-Tectonic maps. A large number of small, generally insignificant faults are also present but are not named. In the coastal zone, the main faults generally trend east-west; in the northern part of the County they are generally northwest-southeast, thus conforming to the two predominant trends in California.

North of Santa Ynez Valley, major structures are the north and south Cuyama faults, their eastern extension. the Ozena fault. and the Nacimiento fault*, a major feature which extends from near Monterey southward to join the Big Pine fault near Big Pine Mountain. The Big Pine fault, itself a major southern California fault, extends eastward as far as the San Andreas fault, some twenty-five miles east of the Santa Barbara - Ventura county line. South of Big Pine Mountain, major Santa Barbara County faults include parallel and sub-parallel faults like the Little Pine, Camuesa, Hildreth, Munson, and Tule Creek fractures. It is probable that these faults are related to the Nacimiento fault system of the Coast Range province.

The Nacimiento fault is the major structural feature of the southern Coast Ranges, although its history is the least known of all California's major fault zones. This is due partly to the region's poor accessibility and partly to apparent inactivity along the fault for perhaps a million years or more. This fault is believed to have significant strike slip in a right lateral sense, with coastal segments moving northwestward relative to the landward block. The Nacimiento system is actually a complex network of parallel and subparallel faults, which, in Santa Barbara County, broadly includes the Cuyama, Suey, Little Pine, Camuesa, and western segment of the Big Pine faults. Although these faults appear to be related, the Little Pine is a thrust, the Big Pine a reverse with left lateral slip, and the Camuesa an oblique fault with at least some right lateral slip.

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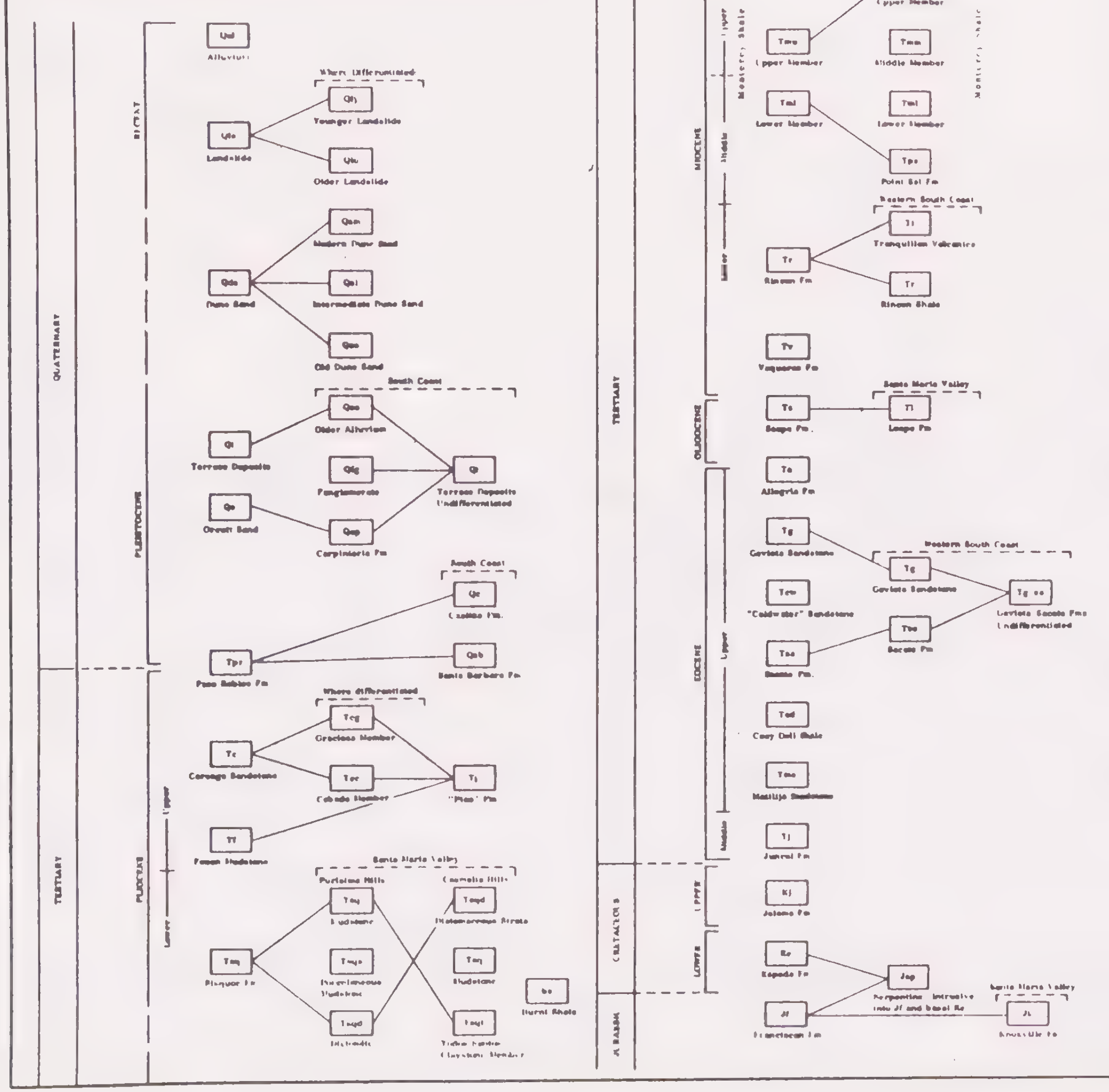
* This name has been applied to several different faults. We follow the usage of the California Division of Mines & Geology, as shown on the 1:250,000 state geologic map sheets (Los Angeles, San Luis Obispo).

REFUGIO FAULT
SAN JOSE FAULT
SAN PEDRO FAULT
CARNEROS FAULT
DOS PUEBLOS FAULT
EAGLE FAULT
LAS VARAS FAULT
GLEN ANNE FAULT
NAPLES
COMPUTER ANALYSIS AREA BOUNDARY
State Route 154
Cathedral Oaks Road
Fairview Avenue
U.S. HIGHWAY 101
Hollister Ave
Foothill Road
La Cumbre Road
Las Palmas Drive
GOLETA
AIRPORT
ISLA VISTA
MORE RANCH FAULT
Ward Memorial Boulevard
Storke Road
ELLWOOD
UCSB
LAVIGIA FAULT
MESA FAULT
Las Positas Road
Cliff Drive
SANTA BA
GAVIOTA
U.S. HIGHWAY 101
REFUGIO F
EL CAPITAN
ERBURU F
DOS PUEBLOS FAULT
N
GEOLOGIC MAP

South Coast Study Area ~ West
Geologic Map

Stratigraphic Explanation (Includes only formations occurring within boundaries of urban study areas)



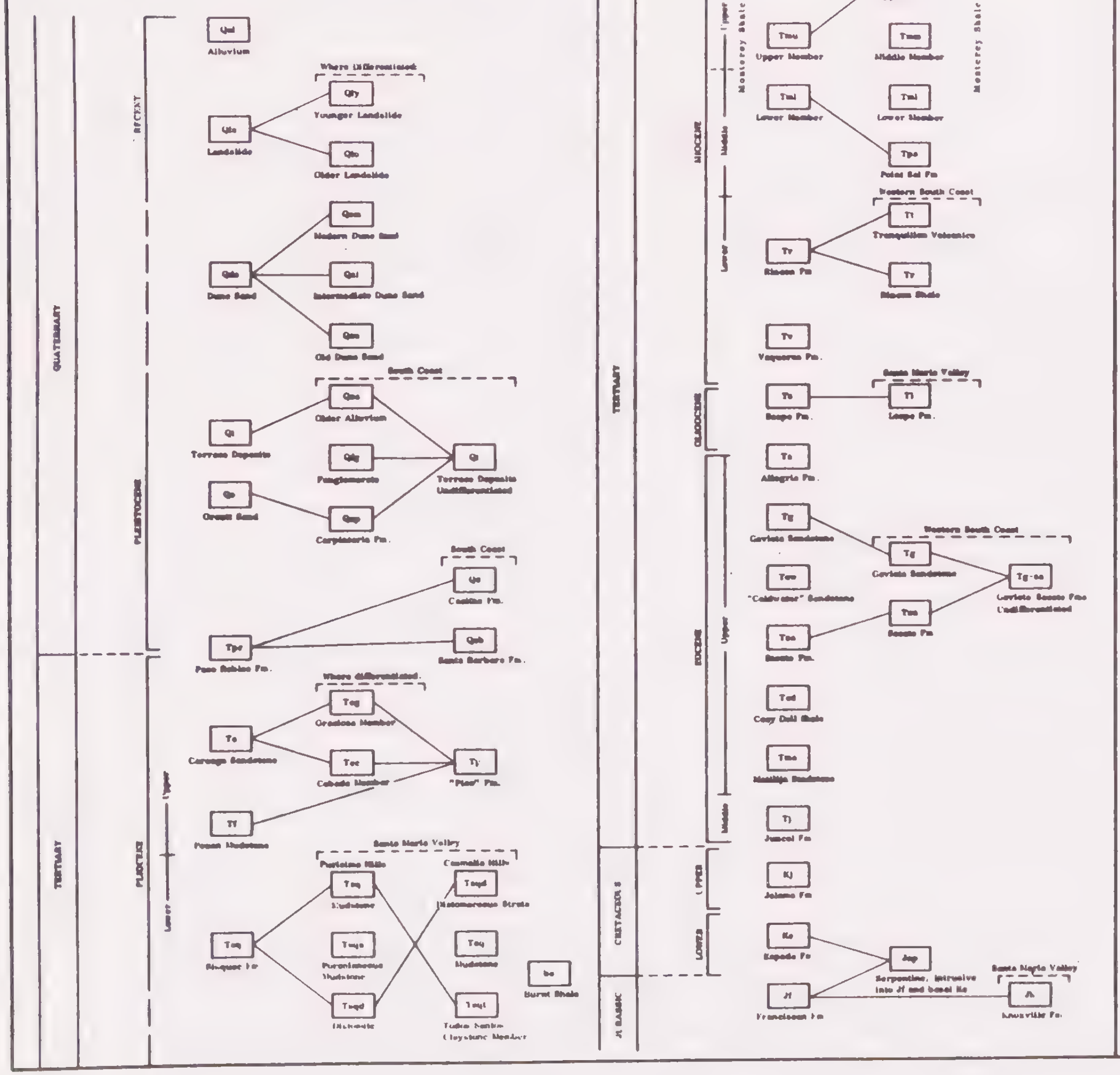
- Contact Between Formations
- Inferred Contact
- Concealed Contact
- Fault, Showing Dip and Relative Movement U - Upthrown Side, D - Downthrown Side
- Inferred Fault
- Concealed Fault
- Uncertain Contact or Fault
- Axis of Anticline, Direction of Plunge
- Axis of Syncline, Direction of Plunge
- Strike and Dip of Beds
- Strike and Dip of Overturned Beds
- Strike of Vertical Beds
- Horizontal Beds
- Approximate Dip of Beds, Strike Uncertain
- Conglomerate Beds
- (WS) Location of Fault, Fold, Contact from Water Supply Paper or Other Source

For degree of dip and Geologic Map references, see original 2,000' scale map on file in the County Department of Public Works office.

SANTA
YNP2
FAULT
LOS PADRES NATIONAL FOREST
STUDY AREA BOUNDARY
SANTA BARBARA COUNTY
Canyon Road
East Valley Road
MISSION RIDGE FAULT
MONTECITO
MONTECITO FAULT
ARROYO PARIDA
SNOWBALL FAULT
ARROYO PARIDA FAULT
ANTICLINE
EAST FORK SYNCLINE
State Street
Anapamu St
Milpas Street
Sycamore
San Ysidro Rd
Sheffield Dr
FERNALD POINT FAULT
Toro Canyon Road
Cabrillo Blvd
MESA FAULT
SUMMERLAND
Foothill Road
CARPINTERIA
Linden Ave
Casitas Pass Road
RINCON CREEK FAULT
CARPINTERIA FAULT
Rincon Rd
RED MOUNTAIN FAULT
SANTA BARBARA
N
GEOLOGIC MAP

South Coast Study Area ~East
Geologic Map

Stratigraphic Explanation (Includes only formations occurring within boundaries of urban study areas)



- Contact Between Formations
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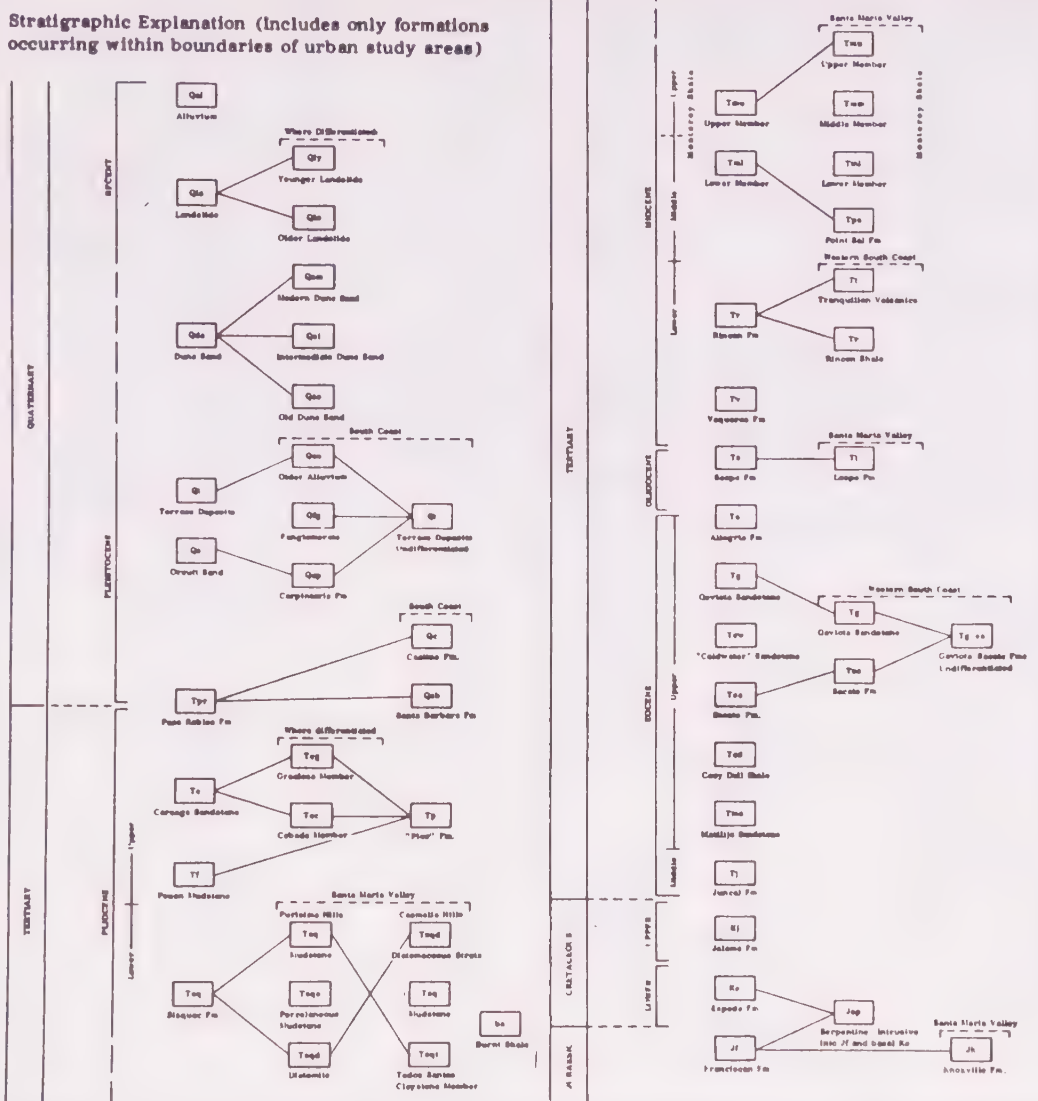
Santa Ynez Valley Study Area Geologic Map

Stratigraphic Explanation (includes only formations occurring within boundaries of urban study areas)



Contact Between Formations

Inferred Contact

Concealed Contact

Fault, Showing Dip and Relative Movement
U - Upthrown Side, D - Downthrown Side

Inferred Fault

Concealed Fault

Uncertain Contact or Fault

Axis of Anticline, Direction of Plunge

Axis of Syncline, Direction of Plunge

Strike and Dip of Beds

Strike and Dip of Overturned Beds

Strike of Vertical Beds

Horizontal Beds

Approximate Dip of Beds, Strike Uncertain

Conglomerate Beds

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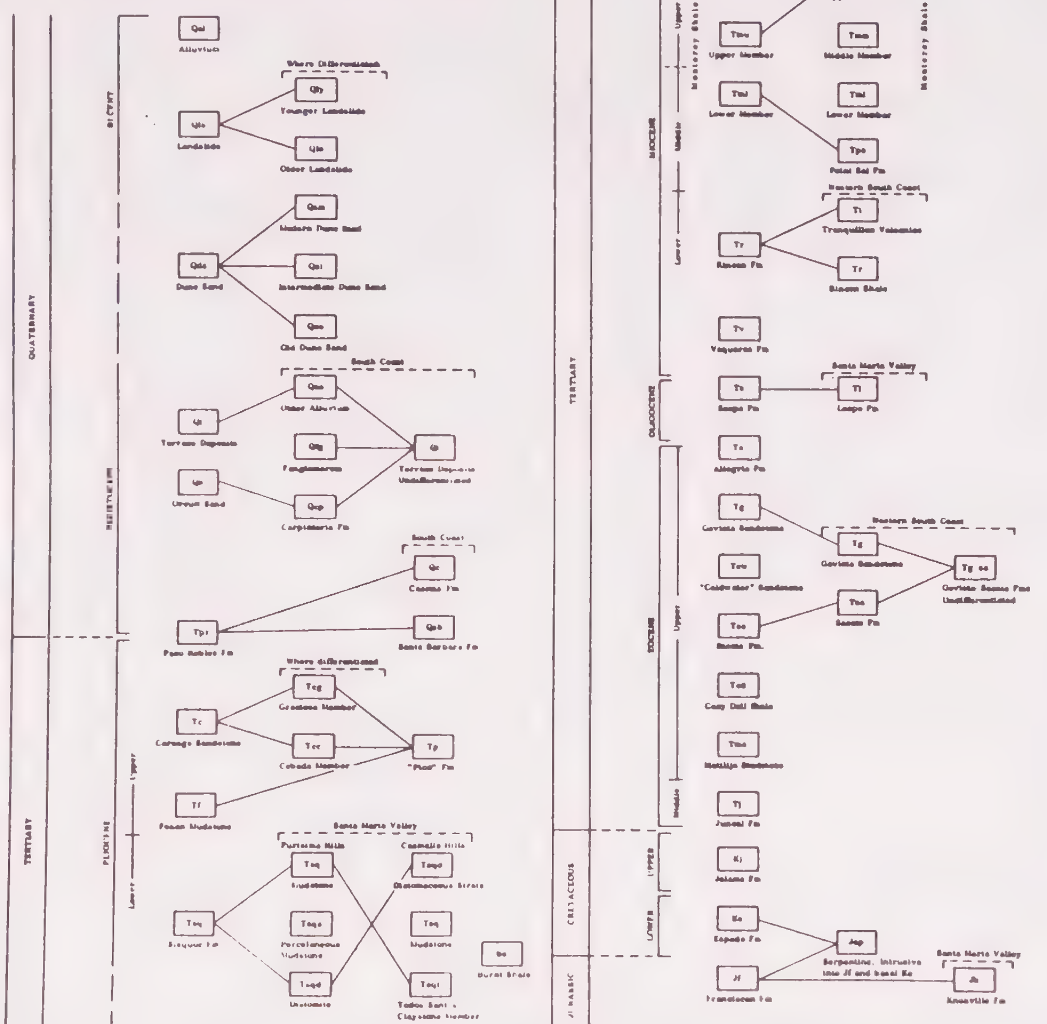
COMPUTER ANALYSIS AREA BOUNDARY
STUDY AREA BOUNDARY
LITTLE PINE FAULT
HIGHWAY 101
LOS OLIVOS
BALLARD
Base Line Avenue
State Route 154
Alamo Pintado Road
Refugio Road
Edison St
SANTA YNEZ
Airport
State Route 246
BUELLTON
SOLVANG
SANTA YNEZ RIVER
(WS)
N
GEOLOGIC MAP

Lompoc Study Area
Geologic Map

Stratigraphic Explanation (Includes only formations occurring within boundaries of urban study areas)



Contact Between Formations

Inferred Contact

Concealed Contact

Fault, Showing Dip and Relative Movement U - Upthrown Side, D - Downthrown Side

Inferred Fault

Concealed Fault

Uncertain Contact or Fault

Axis of Anticline, Direction of Plunge

Axis of Syncline, Direction of Plunge

Strike and Dip of Beds

Strike and Dip of Overturned Beds

Strike of Vertical Beds

Horizontal Beds

Approximate Dip of Beds, Strike Uncertain

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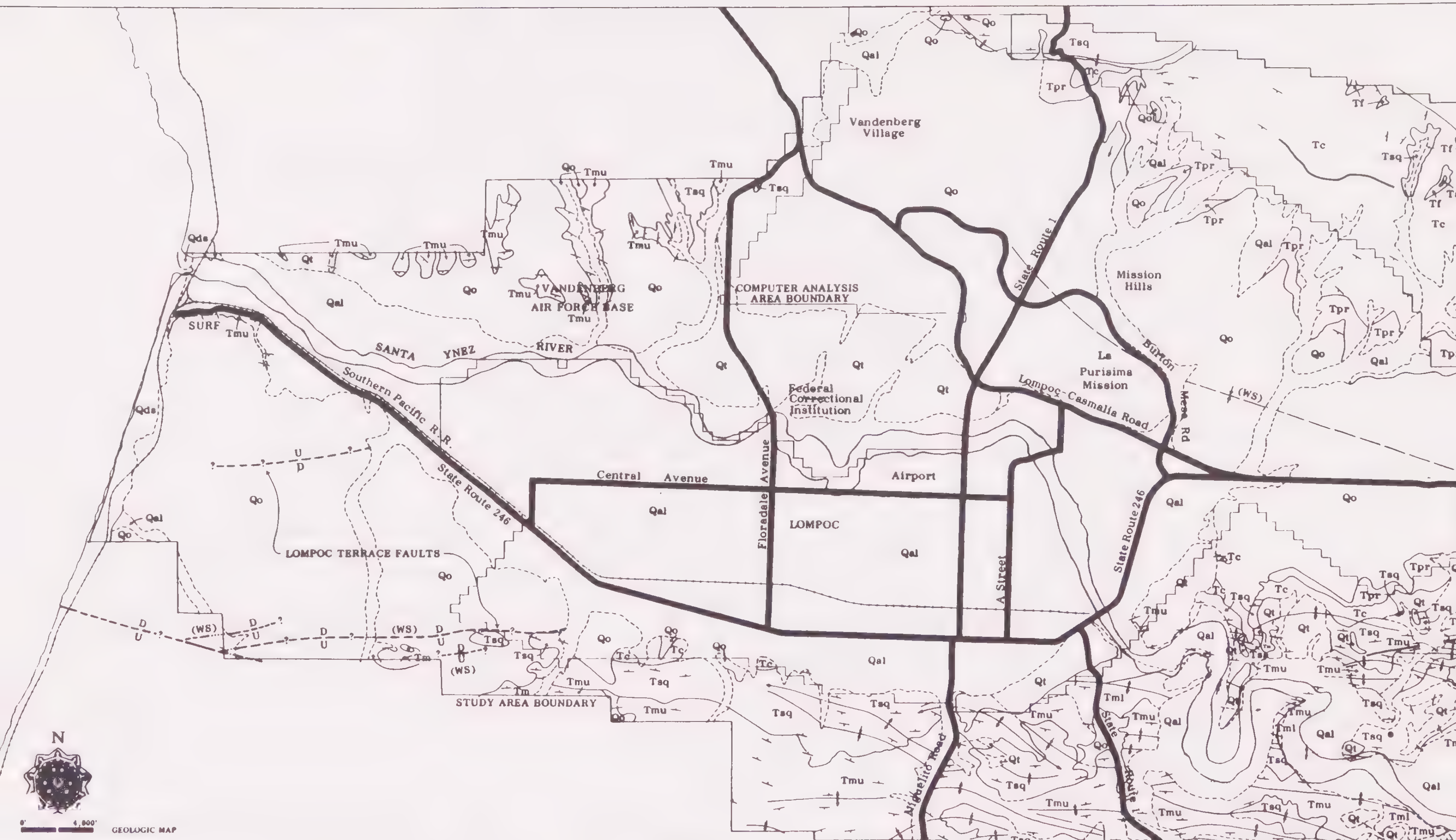
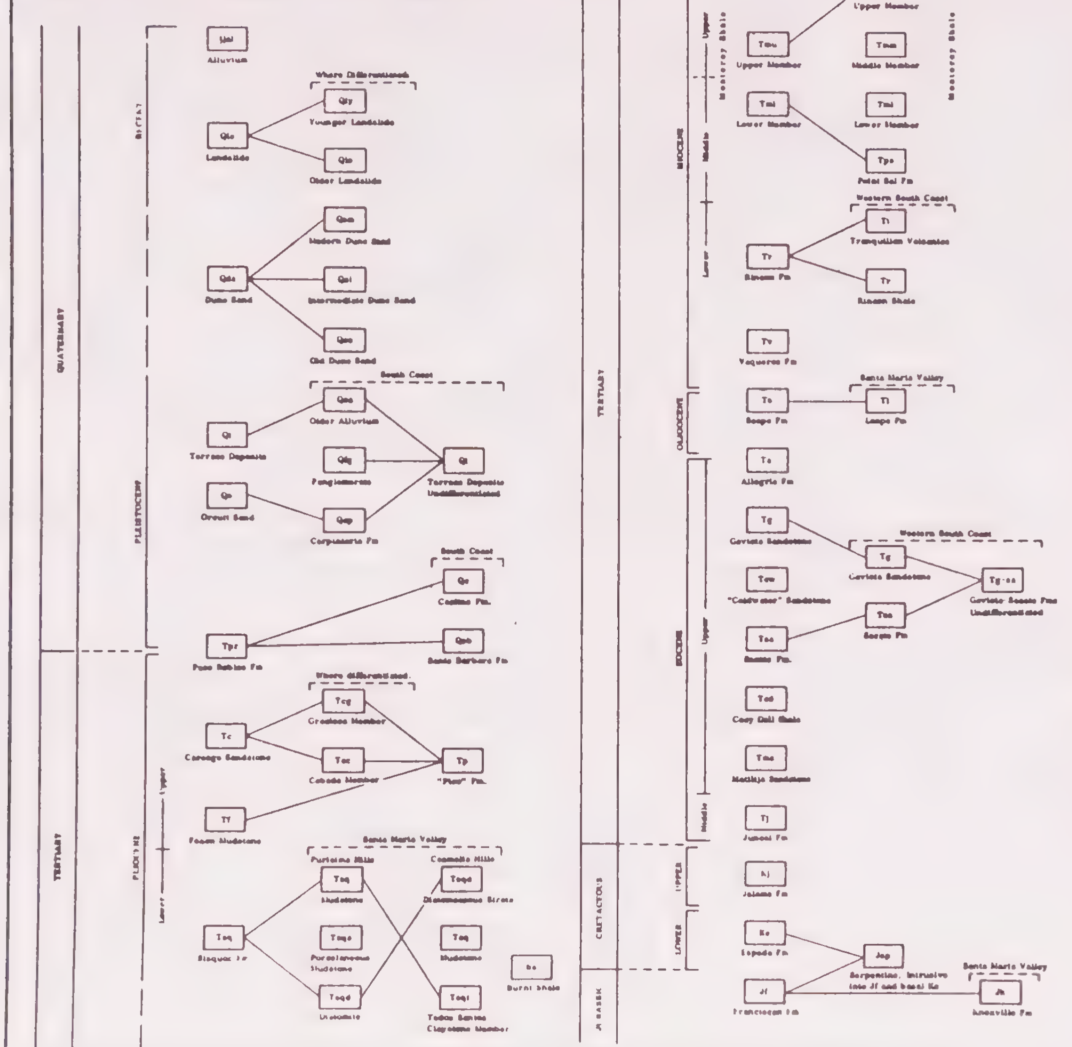


Vandenberg Village
VANDENBERG AIR FORCE BASE
COMPUTER ANALYSIS AREA BOUNDARY
SURF
SANTA YNEZ RIVER
Southern Pacific R.R.
State Route 246
State Route 1
Mission Hills
La Purisima Mission
Burton Mesa Rd
Lompoc-Casmalia Road
Federal Correctional Institution
Central Avenue
Floredale Avenue
Airport
LOMPOC
A Street
LOMPOC TERRACE FAULTS
STUDY AREA BOUNDARY
Miguelito Road
N
0'
4,000'
GEOLOGIC MAP

Santa Maria-Orcutt Study Area
Geologic Map

Stratigraphic Explanation (Includes only formations occurring within boundaries of urban study areas)



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SAN LUIS OBISPO COUNTY
SANTA BARBARA COUNTY
SANTA MARIA RIVER
GUADALUPE
State Route 166
SANTA MARIA
BRADLEY CANYON FAULT
SANTA MARIA VALLEY SYNCLINE (WS)
COMPUTER ANALYSIS AREA BOUNDARY
Stowell Road
Santa Maria Valley R R
Black Road
Betteravia Road
Blosser Road
STUDY AREA BOUNDARY
PEZZONI ANTICLINE
POINT SAL
Point Sal Beach State Park
BETTERAVIA
Santa Maria Airport
State Route 135
State Route
SANTA MARIA FAULT (WS)
PEZZONI FAULT
U S HIGHWAY 101
Clark Avenue
LIONS HEAD FAULT
CASMALIA ANTICLINE
VANDENBERG AIR FORCE BASE
ORCUTT
GRACIOSA ANTICLINE
Southern Pacific R R
CASMALIA
N
GEOLOGIC MAP

The major east-west fault is the Santa Ynez. It extends from near Jameson Lake on the upper Santa Ynez River, westward through Blue Canyon and Forbush Flat on the north slope of the Santa Ynez Range near Gibraltar Reservoir, to near Gaviota Pass where it branches. The south branch of the Santa Ynez fault strikes out to sea near the mouth of Alegria Canyon a few miles west of Gaviota Beach. The other branch continues westward to join the Pacifico fault, which dies out in the upper part of the Jalama Creek drainage. This fault system can be characterized as a high angle, oblique slip fault with appreciable left lateral slip.

On the south flank of the Santa Ynez Range and beneath the coastal plain, there are a number of faults parallel and subparallel to the mountains. Eastward from Gaviota Pass, the main faults are the Refugio, Carneros*, Dos Pueblos and Eagle, Glen Anne, San Pedro and San Jose, More Ranch, Lavigia, Mesa, and Mission Ridge. The Carpinteria and Red Mountain faults strike eastward into Ventura County from the eastern coastal plain. Only the More Ranch - Mission Ridge - Arroyo Parida faults form a persistent and probably continuous structure extending into Ventura County to the east. All these faults may owe their origin to the same stresses that produced the Santa Ynez fault to the north, though positive evidence of this direct relationship is lacking.

Some geologists relate the Santa Cruz Island fault to the Malibu fault, a major Transverse Range structure paralleling the Santa Ynez fault and of similar movement pattern.

Most of the coastal plain faults have steep dips with major dip-slip components. The Glen Anne, Dos Pueblos, and Eagle faults are short and cross the flat-lying coastal plain. They are less obvious because of the terrain they traverse, but well records and groundwater level variations affirm their presence and imporance. In the foothill area, the Carneros fault is traceable for eight or nine miles and has a vertical displacement of about 1500 feet upward on the coastal block. The More Ranch, Lavigia, and Mesa faults underlie the heavily developed Goleta - Santa Barbara areas. These faults are poorly exposed, but escarpments such as the northeast-facing mesa overlooking downtown Santa Barbara is recognized as the result of upthrust of the coastal block. Maximum vertical displacements on any of these faults is probably not more than 2500 feet. Though topographic evidence for current movement is meager, indirect evidence suggests that these faults

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* The Cameros fault was so named by M. L. Hall in 1932. The canyon for which it was named was evidently incorrectly shown on a topographic map used by Hill. Upson, in 1951, shows the name as Carneros, which is the correct name for the canyon.

may become active at any time.

For example, the 1925 Santa Barbara earthquake was occasioned by the sudden slip of an offshore fault, perhaps the seaward extension of the Mesa fault. Some of these faults have juxtaposed relatively young late Pleistocene deposits against older rocks. It is likely that past movement on the Mesa and Lavigia faults is responsible, in part, for the dips of 40° or more that are observed in the Plio-Pleistocene Santa Barbara Formation near the yacht harbor.

Uplifted marine benches at Lavigia Hill, Hope Ranch, More Mesa, and Goleta Mesa, to elevations of as much as 600 feet, certainly indicate young or recent tectonic activity, although much of this elevation is difficult to relate positively to faulting.

The major Mission Ridge - Arroyo Parida fault zone forms the boundary of the coastal plain and the Santa Ynez block north of Montecito and is responsible, to some extent, for the sharp relief of the Santa Ynez mountain front. The Santa Barbara Riviera (Mission Ridge), a highly developed residential area built on the somewhat unstable Monterey formation, has been formed partially by movement on the Mission Ridge fault zone, which passes mostly north of the Riviera proper.

Folding

Most of the hills and mountains in Santa Barbara County are folded to some degree. The low range of hills in the northwestern part of the County are primarily simple anticlinal arches, slightly eroded and usually faulted to only a minor degree. These archlike folds are separated by downwarped or synclinal valleys. That topography conforms so perfectly to structure indicates geologically recent folding; erosion has not yet had sufficient time to erase or modify this correspondence. In the San Rafael Mountains, where folding may be much older, topography conforms imperfectly to underlying structure. For example, Cachuma Mountain is synclinal and San Rafael Mountain anticlinal.

Depending upon how one assesses the situation, the Santa Ynez Range may be described as either a faulted anticline or a southward-dipping homocline raised on the north along the Santa Ynez fault. Those who favor the anticlinal concept note that northward dipping rocks occur just north of the Santa Ynez fault and compose many of the same formations found in the main part of the range to the south. Another way of viewing the Santa Ynez Range is to consider it the steep northern side of a

large synclinal structure comprising the Santa Barbara Channel or the western part of the Ventura basin.

Although most of the range is a homoclinal structure, it is crossed obliquely by several folds that are especially prominent on either side of San Marcos Pass and account for this sag in the range. The highway more or less follows the axis of a syncline. East of Gibraltar Road, the dips in the rocks steepen, first becoming vertical and then, as one continues east, overturning to the north. Overturned beds are defined as beds folded more than 90° from their original depositional position. Such structure is evident from about Romero Canyon eastward as far as the Ojai Valley in Ventura County.

Perhaps the most important consequence of folding is the development of anticlinal folds in porous and permeable sedimentary rocks. These provide traps in which petroleum and natural gas have accumulated at a number of places in Santa Barbara County. Most of the anticlinal traps evident from surficial geology have been drilled. There is always the possibility that additional traps, not evident from surface geology, may contain oil and gas; it is unlikely, however, that accumulations of large size have been overlooked.

THE SHORELINE

Santa Barbara County has a distinctive and long shoreline for a county of its size. The western coast, from the mouth of the Santa Maria River south to Point Arguello, a distance of about twenty-five miles, trends more southerly than the California coast generally, and is interrupted by prominent rocky headlands such as Point Sal and Purisima Point. From Point Arguello to Point Conception, the coast forms an open, curving bight facing southwest. This segment of the coast is about fifteen miles long. From Point Conception, the coast trends nearly due east for almost seventy miles to Rincon Creek. This is the longest east-west trending coast on the Pacific shore of the United States, excluding Alaska. In addition, the three islands lying off the south coast have an east-west trend and add about 200 miles to the County's shoreline.

The Western Coast

This part of the shoreline is the most exposed in Santa Barbara County and experiences the full brunt of Pacific winds and waves. The northernmost portion is sandy beach, which grades inland into the extensive Guadalupe sand dunes. In one place, these active dunes extend inland about two miles. (Ancient dunes extend about twelve miles inland to the town of Sisquoc.) It is likely that the Santa Maria River and other streams to the north furnish the sand supply for the beaches here and in turn, as the persistent northwesterly winds blow sand inshore, for the dunes as well.

Point Sal is a prominent headland formed by marine erosion of the seaward end of Point Sal Ridge. The beach is narrow here, with many parts exposed only during lowest tides. Because of rock resistance at Point Sal, there is a short stretch of east-west trending shore on the south side of Point Sal Ridge. Beginning about two miles southeast of Lion's Head (a rocky point southeast of Point Sal), the beach again is flanked inshore by extensive dunes. These dunes occur more or less continuously southward to Point Pedernales, about two miles north of Point Arguello, although they are quite narrow south of Purisima Point.

Some cliffs occur even along this portion of the coast, and one rocky headland, more or less surrounded by dune sand, occurs at Purisima Point. In many places, dunes have a steep seaward slope, in some instances over 100 feet high. It is likely that these steep dunes cover an old sea cliff because, at a number of places, a narrow strip of exposed bedrock is present behind the beach and below the dunes. Such an exposure is present from near Purisima Point almost to the mouth of the Santa Ynez River. It begins

again about two and a half miles south of Surf, extending to near Point Pedernales where the dunes end.

The Monterey Formation accounts for the greater part of rocks exposed in the sea cliffs in Santa Barbara County. This rock is chiefly a hard, splintery, silicified shale, but in many places it is a soft diatomaceous shale. It contains numerous thin beds of volcanic ash, is often tightly folded or crumpled, and in many places is shattered or fractured extensively. The weaker portions of the Monterey formation are readily eroded by both marine and non-marine processes.

Mussel Rock, a small headland at the south end of the Guadalupe Dune Field, is formed from the Monterey Formation, but the prominent Point Sal headland is carved mainly from the more resistant suite of rocks that are known collectively as the Franciscan Formation. This formation includes an assortment of hard, crystalline volcanic rocks, some soft serpentine, very hard cherts, and some well-cemented sandstones. The general durability of these rocks accounts for the prominence of the headland at Point Sal. Some softer rocks, consisting of siltstone and soft shale of the Point Sal Formation, together with tuffs, conglomerates, and sandstones of the Lospe Formation, do occur between Mussel Rock and Lion's Head. At Lion's Head, the Monterey Formation is exposed again.

Bedrock exposed from Purisima Point southward to the mouth of the Santa Ynez River is Monterey Formation. Bedrock is first encountered beneath the covering dune and beach sand about two and one-half miles south of Surf, where the Sisquoc Formation is exposed.

The Sisquoc Formation is less silicified than the Monterey, but no more durable. It is a thin-bedded, rather soft, somewhat punky, diatomaceous shale, which responds to erosion in much the same manner as the Monterey.

The Southern Coast

Apart from two short stretches of coast, one at Point Pedernales and the other near the mouth of Canada del Rodeo northwest of Jalama where volcanic rocks are present, the entire coastal cliff from two and a half miles south of Surf to the city of Santa Barbara is formed from either the Monterey or the Sisquoc Formations. Thus, this coastal cliff can be expected to respond to marine erosion in much the same way throughout. One minor exception occurs on the south coast at More Mesa between Goleta Slough and Santa Barbara, where a massive siltstone forms a particularly high, steep cliff. This siltstone has been assigned

to the Pico Formation by several geologists, although the assignment is disputed.

A low alluvial coast occurs at Santa Barbara. This is replaced eastward by low bluffs cut in the non-marine Casitas Formation near Santa Barbara Cemetery. Alluvial materials again make up the low bluff from Santa Barbara Cemetery eastward as far as Ortega Hill at Summerland, where coarse, land-deposited gravels and the Casitas Formation form a bluff 100 feet high. Most of the bluff below Summerland is cut in these coarse alluvial gravels, but a short stretch of the coast near Loon Point is eroded from the Casitas Formation.

The low coast from Loon Point to near Carpinteria State Beach is chiefly a wave-deposited sandy beach with a low-lying alluvial plain to landward. At Carpinteria Salt Marsh, or El Estero, the beach is a cuspate headland or a low sandbar developed in the lee of a nearly submerged rocky reef which is exposed off Sand Point only at the lowest tides. Although this reef is not large, it has provided enough shelter from waves to allow the headland at Sand Point to develop.

Finally, from Carpinteria State Beach east to the county line at Rincon Creek, the sea cliffs are formed, once again, from the Monterey Formation.

THE OFFSHORE ISLANDS

Santa Barbara County includes four offshore islands: Santa Barbara, Santa Cruz, Santa Rosa, and San Miguel. Of these, Santa Barbara Island and nearby tiny Sutil Island are far to the southeast of the three Channel Islands. These two small islands are part of Channel Islands National Monument. Both are composed of basaltic lava flows that have been cut into steep cliffs as much as 500 feet high. There are no beaches on either island.

Santa Cruz Island embraces a wider variety of rock types than much of the mainland County and includes the County's only exposed granitic rocks and its oldest rocks as well (the Santa Cruz Island schist of middle or early Mesozoic age). For the most part, the shore is composed of bold, rocky cliffs, some rising 500 feet from the sea. Generally, beaches are small pocket beaches found at the mouths of canyons, but some longer stretches of sandy beach do occur, especially on the western and southwestern end of the island. Although much of the island's coast is cut into volcanic rocks (some of which were quarried to build the Santa Barbara breakwater in the late 1920's and early 1930's), extensive stretches of coastal cliffs, especially

about the isthmus near Chinese Harbor, are formed from the Monterey Formation. In Chinese Harbor, there is a landslide that is kept active by a burning oil seep. The seep causes the shaly rock, baked by the smouldering fires, to crumble and slide down to the sea as talus.

The pattern of beaches is roughly similar on Santa Rosa Island, although well-developed beaches are more prominent and constitute a greater percentage of the coast than they do on Santa Cruz. Most of the coastal cliffs on Santa Rosa are cut from the Monterey Formation, which has a more varied lithography here than on the mainland coast or Santa Cruz. In addition to the typical siliceous and diatomaceous shales usually present in this rock unit, it includes a coarser-grained sandstone, breccia, and conglomerate, plus a considerable thickness of tuffaceous rock indicating a more voluminous contribution from volcanic sources than is characteristic of the mainland Monterey.

Some volcanic flows and volcaniclastic rocks occur along the Santa Rosa Island coast, but they are much less prominent on this island than on Santa Cruz or San Miguel to the west.

San Miguel Island, the windswept, westernmost island in the chain, has a lower elevation than Santa Rosa or Santa Cruz to the east and has proportionally much more sandy beach than either of the two other islands. The prominent rocky headlands in the eastern half of the island are formed chiefly from volcanic rocks. In the western part of the island, the rocky cliffs are cut mostly in relatively durable Cretaceous and early Tertiary sedimentary rocks, which are generally more resistant and firmly cemented than the Monterey Formation.

AREAS OF SPECIAL GEOLOGIC INTEREST

Point Sal Area

This region, from near Mussel Rock, southeastward along the coast to the mouth of Shuman Canyon, and inland to the crest of the Casmalia Hills (or Point Sal Ridge as it is sometimes called), contains one of the best ophiolite sequences in California. These sequences are unusual groups of igneous and sedimentary rocks, widely believed to represent deep ocean floor materials plastered against the edge of the continent during the process of sea-floor spreading. Many classes and research investigators visit this remarkable area. Part of the area lies within Point Sal State Beach Park and part within Vandenberg Air Force Base, but most is on private ranch lands.

Guadalupe Dunes

This environmentally sensitive area extends from the mouth of the Santa Maria River southward to Mussel Rock and inland a maximum of two miles. There is a sand mining operation in the central portion of this area and a small County park in the northerly portion. In recent years this area has been disturbed by off-road vehicle use.

Type Locality, Santa Barbara Formation

This highly fossiliferous shallow marine deposit was first described from exposures near Cabrillo Boulevard and the City College football field in Santa Barbara. The remaining exposures should be preserved.

Carpinteria Tar Pits

An active tar seep containing fossil vertebrate remains of type and variety similar to those found in La Brea Pits in Los Angeles occurs near the coast adjacent to - and possibly partly within - the Carpinteria State Beach Park. Any portion of these tar pits outside park property should be added to the park eventually and protected.

San Miguel Island

San Miguel Island is government property, under the nominal management of the Navy and the National Park Service. This island includes a relatively undisturbed insular area with fine coastal sand dunes, a wide variety of rock types, and an elevated marine terrace. It is also of interest anthropologically.

Nojoqui Falls

This small but scenic waterfall, with a well developed travertine deposit, is located on private land, just south of the County Park.

Type Locality, Refugian Stage

This locality forms the standard for this stage of Cenozoic time for the west coast of the United States. The micro-fossil assemblage is thus considered a "classic" example of the small life forms prevalent at the time. It lies on the Hollister Ranch in Santa Anita Canyon which has been recently subdivided into 100 acre lots. Although development could pose a problem, difficulty of access presently protects the area.

Zaca Lake

This lake, located in the southwest portion of the San Rafael Mountains, was formed by a landslide which blocked drainage of a canyon. It is of geologic interest because it shows how the topography can be significantly changed by massive landsliding.

IV. Geologic and Seismic Hazards

INTRODUCTION

Factors in Land Use Planning

Geologic, soil, and seismic factors affect the suitability of land for various uses and, hence, should be considered, along with other factors, in land use planning in order to eliminate or minimize their adverse effects. However, a distinction should be made - even though it cannot always be sharply drawn - between problems for which there is a practical and economically feasible solution and those for which there is not. For some problems, such as ground offset as a result of fault displacement, it is not practical to solve the problem by engineering. In others, such as large landslides, solutions will exist, but they may be prohibitively expensive. However, some geologic problems such as expansive soils do not have a major impact on development and can be compensated for in design at a relatively moderate cost. The following tabulation provides a very rough classification of factors to be considered in land use planning.

Critical

Ground rupture from fault movement
Tsunamis and seiches
Liquefaction

Sometimes Critical

Groundshaking
High groundwater
Subsidence (normally correctable with engineering)
Slope stability and landslides
Soil creep

Less Critical

Expansive soils
Compressible - collapsible soils

Ground rupture from fault offset and tsunamis and seiches are the only geologic problems for which there are no really feasible engineering solutions, and which could be considered as dominant factors in planning (assuming fairly frequent occurence). Items lower on the list should also be taken into account during development, and probably should be given some consideration in planning land use or density. However, an owner or prospective developer could argue that if a problem can be solved by engineering or appropriate site preparation to meet building standards, his property should not be subjected to planning constraints, provided that he is willing to spend

the money necessary to solve the problem.

The emphasis of this study, as required by State law, was to prepare a seismic safety element evaluating seismic problems and related hazards. However, other soil and geologic problems deserve serious consideration, and also were investigated as to their possible effect on land use planning and safe, prudent development of property.

Basis for Evaluation

Types of Data - In order to evaluate the severity of the various types of problems, two approaches to data collection and analysis were used. One was to obtain areal geologic maps and reports from various sources such as the U. S. Geological Survey and U. S. Soil Conservation Service. From this basic information, the potential effects of the various problems on residential and commercial development was estimated. This method is by its very nature general and somewhat subjective.

A second approach, utilized in limited areas where data are available, was to determine those factors or situations that have caused problems in the past. Most geologic problems occur regardless of the presence of man. However, in undeveloped areas they usually have relatively little impact and frequently go undectected. Hence, the relatively heavily developed South Coast region may appear to have more problems than the rest of the County, but this could be misleading, and these problems could exist in various locations throughout the County and possibly could remain unobserved.

Specific Problems - Some examples of geologic problems deserve brief mention. Seismically related problems, including reported ground rupture and effects of ground shaking, have occurred on occasions during historic time in Santa Barbara County. There are some reports of tsunamis (seismic sea waves) in the past. However, the other main seismically related problems - such as creep along fault tract traces and liquefaction of the soils under seismic shock - are not known to have damaged structures in the County in the past.

Landslides and mass earth movements not associated with earthquakes have damaged structures and caused other problems in the County, notably in the heavily developed southern foothill. Slope erosion has caused trouble throughout the County, notably along the south coastal bluffs, where combined with bedding-plane landslides, erosion has damaged or threatened structures built adjacent to the bluffs.

Expansive soils can cause distress to structures built upon them and have caused problems sporadically throughout the County. The most extreme cases of structural distress have occurred in a belt along the south coastal foothills, where geologic formations outcrop that are either highly expansive themselves or generate highly expansive topsoils. Although expansive soils are a major and frequently under-estimated problem, damage from this source can be minimized with appropriate engineering. However, in hilly areas, the effect of expansive soils in producing creep can be very difficult to overcome and may make dense development impractical without considerable engineering design.

Settlement of the ground surface can occur from consolidation of low density soils, collapse of high void soils upon saturation, or from subsidence due to fluid withdrawal. Settlement from the first two causes occurs sporadically throughout the County in the alluvial flatlands and in poorly-compacted, man-made fills, but subsidence due to fluid withdrawal is not known to have occurred in Santa Barbara County.

Near-surface groundwater in the form of perched water or a static high water table is a problem from several standpoints. A high groundwater table - depending on its depth - may not affect some types of development, but would make use of private sewage disposal systems (seepage pits or fields) impractical. It can affect excavations for utilities, basements, and pools, and require special design. The soils may also be susceptible to liquefaction. A high water table exists in the slough and lowland areas along the South Coast and perched water is found in several locations throughout the County.

With the adoption of stricter engineering and geologic controls on development, instances of damage from certain geologic problems are decreasing. This study will assist in minimizing the occurrence of such problems.

Limitations of "State-of-Seismic-Art"- Certain limitations regarding the overall scope of the work were described under Limitations in the Introduction. For seismic hazards, a special warning is needed. The earth's crust and the faults that transect it form a very complex system. Although the expenditures of time and money spent in the field of seismology have increased very sharply since the San Fernando earthquake of 1971, and our knowledge has also increased substantially, specific solutions are still handicapped by the lack of knowledge and data, particularly the short historic record that provides the time base. Every major earthquake - and particularly the San Fernando earthquake - has added substantially to our knowledge and revised at

least some previously held ideas. It is clear that there is much to learn. Under the present state-of-the-art, we cannot accurately predict which fault will move, when, or even in many cases _if_ it will move. Therefore, detailed seismic zoning is not justified by the present state of knowledge and implies an accuracy that presently is not achieveable. Hudson (1972) has concluded that it is not feasible to seismically zone the City of Pasadena; this conclusion would apply to many other areas of comparable or even larger size.

Geologic Problem Rating System

In order to show the geologic problem ratings in usable form for land use planning purposes, the conclusions regarding the evaluation of the various geologic problems were shown on maps. The maps were designed to stand on their own as technical documents as much as possible; however, a general discussion of each problem is included in the report. The problems have been rated by drawing boundaries on maps of the entire County (excluding the National Forest) at a scale of 1" = 8000' and the study areas at a scale of 1" = 2000'. For a given area, each geologic problem evaluated was given one of three number ratings:

Problem Rating	Description
1	None to low
2	Moderate
3	High

The ratings were based on the relative degree of severity for each specific problem, compared only to the same problem. No attempt was made to compare it to other geologic problems in the original rating. It was generally not possible to give quantified ratings, but the problems were numerically defined for expansive soils, soil creep, and ground shaking.

There is a wide range in the reliability and possible variability of ratings due to lack of basic data, sharp local variations within any designated area that cannot be portrayed at the scale mapped, and possible subjective variations in evaluating the available data. Therefore, a second single digit number indicating the reliability or possible variation was introduced. This second digit is located immediately after the rating number and gives the maximum probable range in the problem rating. Thus, a variability number of 2 means "+1" and indicates that the problem may be one rating higher (more severe) than the basic designation. The meanings of the variability numbers are given below. (Maximum probable range means that there is at least a 90% probability the property lies within the variability limits given.)

Variability Number (Second Digit)	Variation	Variability Number	Variation
1	No variation	4	+2 rating
2	+1 rating	5	-2 rating
3	-1 rating	6	$\pm$1 rating

For example, a 35 rating for any given problem would indicate a high rating (3) with a possible variation (down) of two levels (5). A summation of the problem rating - variation system is shown below.

Problem Rating Description	Numerical Designation	Possible Variation from Assigned Rating
Low	1 1	- no variation
Low	1 2	+1 (moderate)
Low	1 4	+2 (high)
Moderate	2 1	- no variation
Moderate	2 3	-1 (low)
Moderate	2 2	+1 (high)
Moderate	2 6	$\pm$1 (high or low)
High	3 1	- no variation
High	3 3	-1 (moderate)
High	3 5	-2 (low)

For convenience, two geologic problems were plotted on each map, with the problems paired off so that boundaries on the map were common for both problems whenever possible. Six problems were rated in this manner to produce three maps. Examples of the two problem designations for each map are indicated below:

Groundwater Liquefaction	$\frac{21}{22}$	
Slope Stability Compressible Soil	$\frac{33}{23}$	Problem Rating (first digit) Variability Number (second digit)
Earthquake Intensity Tsunami-Seiche	$\frac{33}{11}$	

Of course, even within a given small area, it will not be uncommon for a particular geologic problem to range from low to high. It would not be meaningful to show the full range, if only a small portion of the area is given one of the classifi-

cations. Therefore, the estimated rating and variation have been selected as representing at least 90 percent of the area so designated. For example, if a problem rating of 22 is assigned to a given area, it is believed that at least 90 percent of the area is either in 2 (moderate) or 3 (high). Or, if 31 is assigned, at least 90 percent of the area is estimated to be at level 3 (high - no variation).

Geologic Problem Index

It was deemed appropriate to develop a composite number to give an overall indication of the difficulty to safely develop any particular area, from a geologic point of view. Therefore, a system for rating geologic problems for a given area on both an individual and collective problem basis was devised which could be performed by computer. The resulting collective or cumulative value has been designated the Geologic Problem Index (GPI). Ground rupture is the only geologic problem considered separately, partly because it is such a serious or overriding problem in the limited locations where it occurs and partly because it is a linear rather than areal feature.

When all the different kinds of problems were designated, the rating of each was multiplied by a weight factor that approximately represents the magnitude of the problem involved in developing an area with respect to the weight factors for the other problems. The weight factors were chosen on the basis of the effect of the following considerations assuming a high rating (3) for each problem.

1. Consequences of the problem, that is whether or not property damage or loss of life would result and whether it would be moderate or severe.

2. Frequency of occurrence assuming no special precautions were taken. This was difficult to evaluate because some conditions such as expansive soils are constantly present, while tsunamis may be many decades or even centuries apart.

3. Difficulty of prevention. Some problems are relatively easily prevented. Others are very expensive or even impossible to prevent.

The values resulting from multiplying the rating of each problem by its weight factor have been summed to give a GPI. The variation of rating values also has been multiplied by the weighting factors and summed to give a possible range of variation. The

weight factors and an example of a GPI calculation are given below based on a hypothetical hillside area with an unstable geologic formation (e.g., Rincon) in the South Coast region.

Geologic or Soil Problem	Rating 1	2	3	Weight Factor	Weighted Rating
Seismic Severity (ground shaking)			3	18	54
Tsunamis-Seiches	1			19	19
Liquefaction	1			15	15
Slope Stability			3	23	69
Expansive Soils			3	7	21
Soil Creep			3	4	12
Compressible/ Collapsible Soils		2		11	22
High Groundwater	1			3	3
				(100)	GPI = 215

Since the weighting factors were chosen to give a total of 100, a cell with no problems (Rating 1) would have a GPI of 1 x 100 = 100. A cell with severe problems in all categories would be 3 x 100 = 300, and a cell with all problems rated moderate would have a GPI of 200. In actuality, no land lies at the upper limit because some of the problems are unique to hillsides and some are essentially limited to flatland, so that no one piece of ground can have a high rating for all problems. The actual computed range was 100 - 236.

Expansive soils and soil creep were not mapped County wide. Therefore, in order to provide an approximately equivalent basis of comparison with the urban study areas, a moderate rating of (2) was assigned, with a possible variation from low to high ($\pm$1)

It was concluded that some guidance was needed in understanding the significance and meaning of the GPI ratings. In order to simplify the situation resulting from a large number of Geologic Problem Indices, the range of values for the entire County was divided into the following five categories. The limits of these categories were arrived at by applying engineering judgment in an attempt to establish absolute limits based on the theoretical severity of various combinations of problems and ratings, and then modified slightly so as not to have an exaggerated distri-

bution of the number of cells within the categories.

Category	GPI Range	Overall Problem Severity
I	100-125	Low
II	126-145	Low-moderate
III	146-180	Moderate
IV	181-210	Moderate-severe
V	211 up	Severe

A discussion of the application of the categories as well as a computer printout display of the categories are given in the section on Conclusions and Recommendations, page 134.

Two other examples of the application of the GPI rating system for specific areas are given below to compare to the previously rated hypothetical hillside area underlain by an unstable geologic formation such as the Rincon Foramtion. As can be seen from the previous example, slope stability, soil creep, and expansive soils - which are interdependent and associated with each other in some formations such as the Rincon - have a high rating and are dominant factors in the GPI. Because of the hillside location, the area would not be subject to tsunami - seiches, liquefaction or groundwater. Conversely, a flatland area located in the Goleta Slough would be more subject to tsunami, liquefaction, high groundwater and settlement.

Problem	Weight Factor	Isla Vista		Goleta Slough	
Ground Shaking	18	3*	54**	3*	54**
Tsunamis - Seiches	19	1	19	2	38
Liquefaction	15	1	15	2	30
Slope Stability	23	1	23	1	23
Expansive Soils	7	2	14	2	14
Soil Creep	4	1	4	1	4
Compressible Soils	11	2	22	3	33
High Groundwater	3	2	6	3	9
GPI			157		205
Category			III		IV

* Rating

** Weighted Rating

FUNDAMENTALS OF ENGINEERING SEISMOLOGY

Introduction

Earthquake design of important structures requires reasonable engineering decisions concerning the effects of ground motion on the structure. Consequently, the design engineer wants and needs to know as much as possible about the nature of the seismic ground motions to be expected at the particular site during the proposed lifetime of the structure.

The purpose of this section is to provide a very general and basic description of the "state-of-the-art" of earthquake engineering as it relates to the effects of a seismic event on a site under consideration. In addition to a brief presentation of the nature of the earthquake, this section presents some current methods and techniques for estimation of earthquake magnitudes, ground motion parameters, and probable reoccurrence of seismic events.

It should be emphasized that these methods and techniques represent the best information to date, but should not be considered as an exact or absolute solution. In most instances, they represent an average or idealized solution and must be applied in conjunction with considerable engineering judgment. Two events, the Alaskan Earthquake of 1964 and the San Fernando Earthquake of 1971,gave a tremendous impetus to basic research in this country into the nature of earthquakes and their effects. It is expected that earthquake engineering methods will change drastically in the next few years as the results of this research become available.

Realizing that this report will be of interest to persons with varied backgrounds, some of which will not be of a technical nature, an attempt has been made, insofar as possible, to present the material so it may be comprehended by the majority. Where interest is created for a more detailed or technical description, the reader should refer to the Bibliography.

The Nature of Earthquakes

It is generally accepted that the earth's crust is not in a state of absolute quiescence, but that the crust is made up of a small number of adjoining plates, which are moving relative to one another. In the vicinity of the plate boundaries, the tendency for relative displacement between the neighboring regions sets up elastic strain; it is generally held that earthquakes are caused by the sudden release of stress when the earth's

crust fractures or slips at a weak point under an excess of this gradually accumulated tectonic stress. The seismically active areas of the world, such as California, generally lie along plate boundaries. Anderson (1971) describes the theory of plate tectonics as it applies to Southern California.

The point at which the initial rupture occurs and the first earthquake waves radiate is referred to as the focus or hypocenter. The position on the earth's surface directly above the focus is called the epicenter. Seismic waves are produced near the edge of the rupture as it spreads out from the focus, releasing the accumulated strain energy. Consequently, if the magnitude of energy released is significant, as is generally the case for large earthquakes, there will be relative movement between the two sides of the fault at other locations besides the immediate vicinity of the epicenter.

Faults and Earthquakes

A fault is a fracture or fracture zone in the earth's crust along which there has been a displacement of the two sides relative to one another. The displacement may range from a few inches to tens of feet. Cumulative displacements along large faults can total several hundred miles over a long span of geologic time. A fault is generally described and classified by the orientation of its surface and by the direction of its movement. Figure 6 illustrates some types of idealized faults.

If the movement takes place abruptly - as is usually the case - an earthquake results. If the focus (source location) of an earthquake is shallow, the fracture often extends to the surface of the ground where it is recognized as a fault. However, if the focus is deep, or the energy release is small, the fracture may not extend to the surface. Nevertheless, it is believed that the mechanism of nearly all earthquakes is related to faulting whether or not the fault break related to a particular earthquake extends to the surface.

The likelihood of major earthquakes on a particular fault can, in principle, be determined from geological, geodetic and seismological data, such as earthquake history, distribution of epicenters, strain level and rate, and the ages of fault displacements during the last several thousand years. Unfortunately, the geologic data are usually not adequate to estimate the expected frequency of destructive earthquakes on an individual fault (Ziony *et al*., 1973). The age of latest displacement on an individual fault is the criterion for determining potential activity which can be applied most consistently to a regional study of

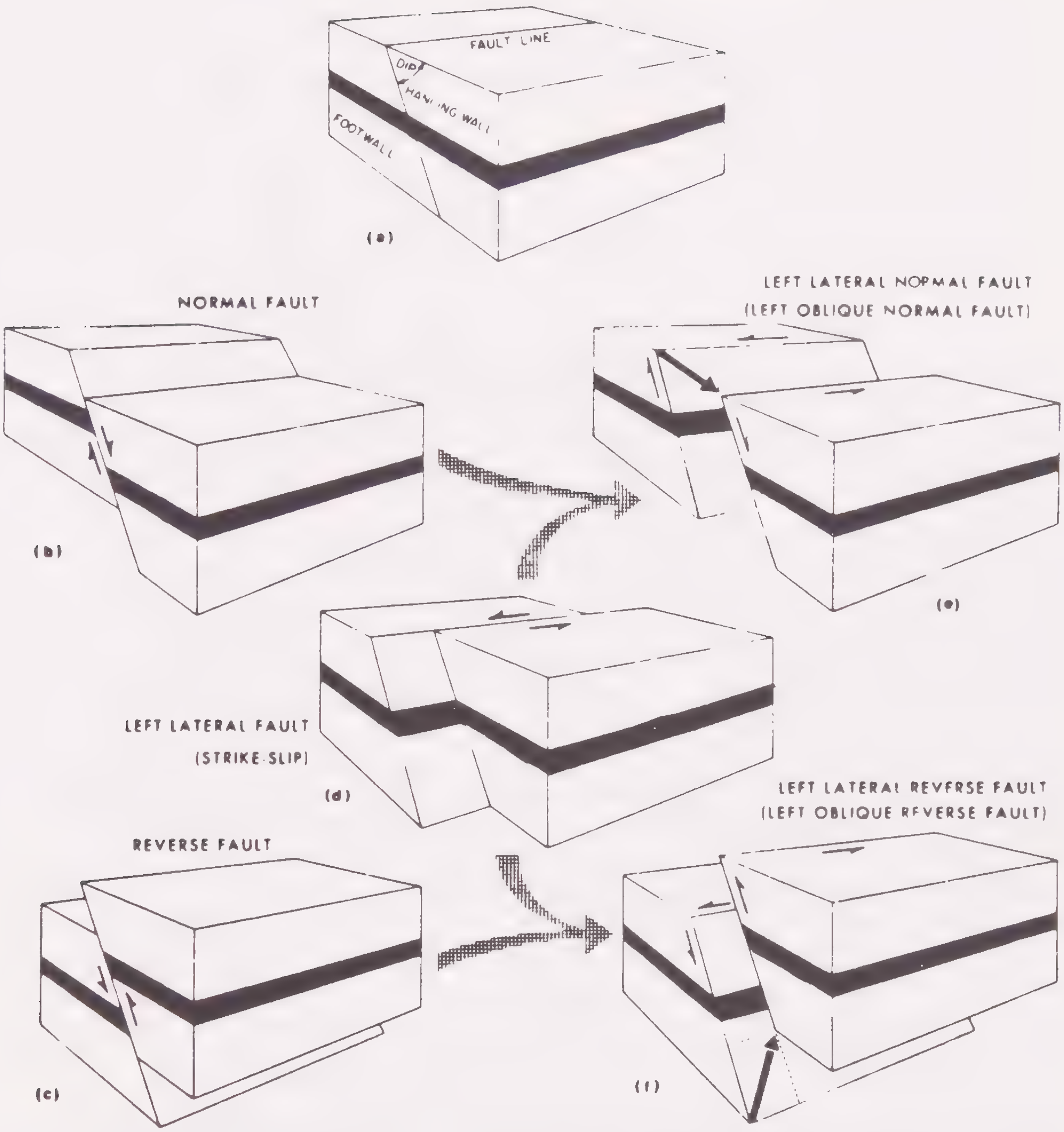


Figure 4. Types of fault movement. a) Names of some of the components of faults. b) Normal fault, in which the hanging wall has moved down relative to the foot wall. c) Reverse fault, sometimes called thrust fault, in which the hanging wall has moved up relative to the foot wall. d) Lateral fault, sometimes called strike-slip fault, in which the rocks on either side of the fault have moved sideways past each other. It is called *left* lateral if the rocks on the other side of the fault have moved to the left, as observed while facing the fault and *right* lateral if the rocks on the other side of the fault have moved to the right, as observed while facing the fault. e) Left lateral normal fault, sometimes called a left oblique normal fault. Movement of this type of fault is a combination of normal faulting and left lateral faulting. f) Left lateral reverse fault, sometimes called a left oblique reverse fault. Movement of this type is a combination of left lateral faulting and reverse faulting. Two types of faults not shown are similar to those shown in e and f. They are a *right* lateral normal fault and a *right* lateral reverse fault (a right oblique normal fault and a right oblique reverse fault, respectively).

FIGURE 6

TYPES OF FAULT MOVEMENT

(from California Geology, November, 1971)

faults. Depending on the preserved geologic record, the recency of movement can be approximated for each fault from geologic or topographic features and historic data. On this basis, the ages of latest movement along individual faults can be compared. With this approach it is often assumed that faults with the more recent displacements are the most active and most capable of producing earthquakes (Ziony et al., 1973). However, a fault may be active, as reflected in frequent small earthquakes or tectonic creep (continuous slow movement, often without earthquakes), and not capable of generating a large destructive earthquake. Elastic strain necessary for a large earthquake may actually be released by the continuous activity. On the other hand, the absence of historic and geologically recent earthquakes could indicate a large accumulation of strain energy and the consequent hazard of an impending large event (Allen, 1968).

Despite these uncertainties, the age of latest displacement is the most useful and easily applied criterion for estimating the future probability of an earthquake on an individual fault. As outlined below, faults are divided into four classes in order of increasing age since the last movement (modified from Cobarrubias et al., 1973).

Historically Active (HA) - Faults for which destructive earthquakes within historic time are reasonably well documented are classified as historically active. In some cases earthquakes have originated on possible sub-sea faults or sub-sea extensions of known faults. Epicenters are not always well located, fault patterns are complex, and individual fault traces are discontinuous and have variable trends. Thus, assignment of historic activity on the basis of an earthquake originating on a possible sub-sea extension of a fault is considered speculative.

Active (A) - Faults that show evidence of displacement during the most recent epoch of geologic time (Holocene or Recent epoch) are classified as active. Ziony (1973) and Ziony et al. (1973) estimate that the Recent epoch began approximately 11,000 years ago. Any topographic reflection of fault displacement is considered evidence that the causitive fault is active because after 11,000 years such evidence would probably be obliterated by erosion and deposition. Figure 7 shows landforms along recently active faults. Some topographic features, as evidence of Holocene displacement along faults in Santa Barbara County, are summarized in Table 1 in the following section.

Fault scarps are formed when the original ground surface is displaced due to fault movement; recent fault scarps are sometimes difficult to differentiate from "fault-line scarps." Fault-line

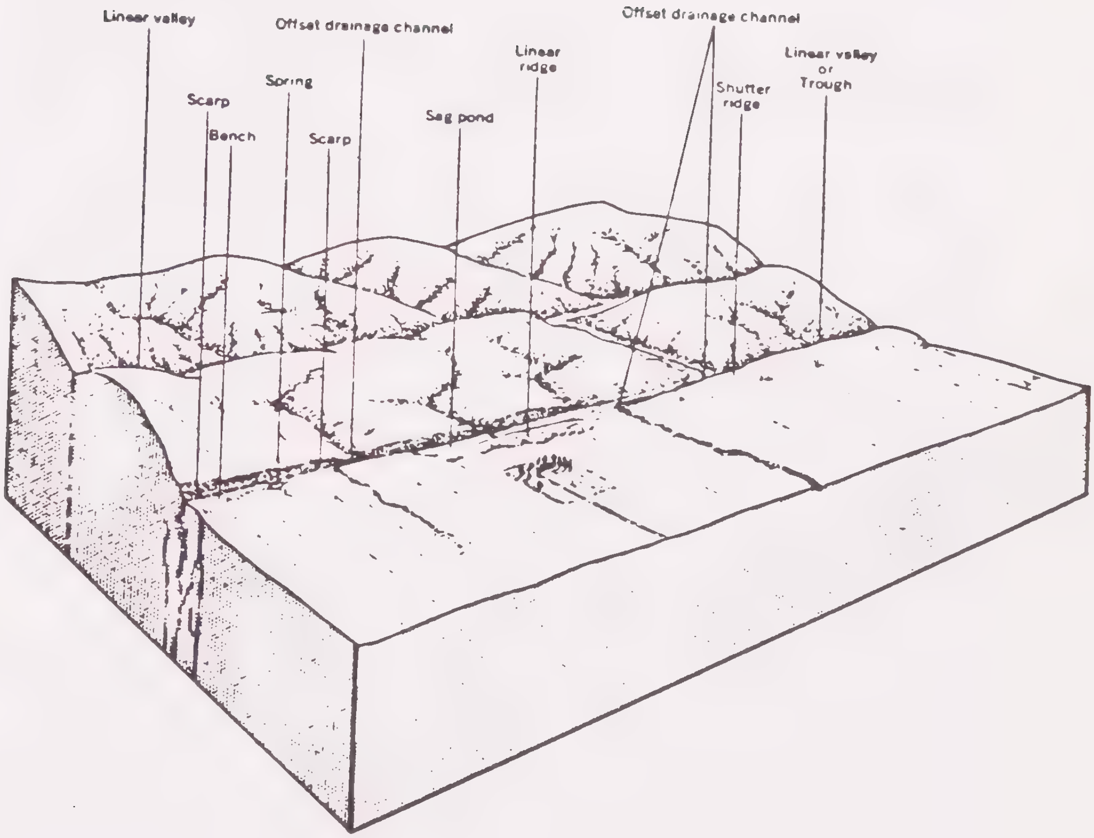


FIGURE 7

LANDFORMS ALONG RECENTLY ACTIVE FAULTS

(from Vedder and Wallace, 1970)

scarps form along faults as a result of greater erosion of soft rocks on one side of a fault trace. If the rocks on opposite sides of a fault have the same susceptibility to erosion, the resulting scarp probably formed as a result of displacement in geologically recent time. Otherwise, the scarp would be substantially obliterated, subdued, and less conspicuous.

Sagponds occupy depressions along recently active faults; the depressions apparently form as a result of uneven settling of the ground within a fault zone during an earthquake. It is estimated that deposition would fill a sagpond within 11,000 years; thus sagponds provide criteria for classifying a fault as active.

Drainage lines may be displaced laterally along a fault. Such offsets would probably be obliterated by erosion within 11,000 years and thus their presence is a good criterion for classifying a fault as active. Caution must be used in identifying such offsets because stream channels may form preferentially along less resistant broken rock in a fault zone. In this case, the direction and amount of offset may be inconsistent.

The youngest alluvium filling drainage courses is considered to be of Recent age; if such deposits are displaced, the fault is classified as active. It should be recognized that rates of erosion and deposition vary widely due to differences in terrain, climate, vegetation and rock type. Thus, the lower age limit of 11,000 years assigned to Holocene (Recent) alluvium and residual topographic features produced by faulting is only an approximation.

Elevation changes have been measured across several faults in Santa Barbara County; this difference is based on comparison of elevations along level lines surveyed in 1957-1960 and 1971 (Willott, 1972). Such elevation differences can be the result of groundwater withdrawal or differential compaction of poorly consolidated sediments present only on one side of a fault rather than tectonic activity (Lamar and Lamar, 1973). Thus, differential ground elevation by itself, is not considered adequate evidence that a fault is active and capable of generating a destructive earthquake.

More or less continuous displacement or creep may occur along a fault without associated noticeable seismic activity. Some geologists believe that such movement may prevent the accumulation of strain energy necessary for a major earthquake. The significance of creep in terms of the earthquake hazard of an individual fault is poorly understood.

Potentially Active (PA) - Faults which displace deposits of late Pleistocene age and show no evidence of Recent (0 to 11,000 years old) movement are considered potentially active. The late Pleistocene is estimated to span 11,000 to 500,000 years before the present (Ziony, 1973). Actually, such young deposits are usually poorly dated because of a lack of fossils and other organic material suitable for radiometric age determinations. Published geologic maps of Santa Barbara County usually indicate that old alluvium, terrace deposits, and fanglomerate are of late Pleistocene age.

The upper surface of old alluvium occurs above the level of present deposition and has been eroded by down-cutting of the main valley and tributary streams. These deposits are older than the alluvium presently being deposited in the main stream valley. If erosion proceeds to the point where only isolated outliers of alluvial sediments cap high points, such deposits are usually classified as river or stream terrace deposits.

Fanglomerate consists of material deposited in an alluvial fan. Dibblee (1966) considers the fanglomerate in the Santa Barbara area to be of late Pleistocene age because it is dissected and contains hugh boulders which were probably deposited by torrential downpours considered typical of the Pleistocene ice ages.

We have followed usual convention and consider these older alluvial deposits to be late Pleistocene in age. This age designation is primarily based on the fact that the pre-existing alluvial deposit has been eroded. The erosion presumably occurs because the deposit has been uplifted or the main valley has downcut. Actually, in the Santa Barbara area, there is no assurance that the required uplift or downcutting and erosion occurred more than 11,000 years ago. Thus, the distinction between "active" and "potentially active" faults is difficult to define.

Inactive - Faults that only displace rocks of early Pleistocene age or older (500,000 years old or older) and show no evidence of more recent movement are classified as inactive. Early Pleistocene to late Pliocene sediments fill many of the lowland valleys in Santa Barbara County. These deposits are often conformable (no discordance in structure) with overlying late Pleistocene and Recent deposits. They are commonly not well dated because of a lack of fossils and material suitable for radiometric age determinations. Thus, the 500,000 years upper age for early Pleistocene deposits is usually not well established, and faults which displace such deposits should be considered a greater hazard than faults which displace only older rocks. Cobarrubias *et al*

(1973) have recognized this distinction and classified such faults as "Potentially active, subgroup two - low potential."

In the overall geologic picture, the majority of faults fit into the inactive category. Geologic mapping usually shows that bedrock at any site contains faults of various sizes, most of which have been quiescent for millions of years. Such faults constitute no significant earthquake risk. For engineering design, it is only faults within the first three categories (HA, A, PA) which require consideration and judgment regarding the likelihood and effects of seismic activity within the lifetime of the project.

Parameters Describing Earthquakes

In the following few pages, the principal parameters used by earthquake engineers to characterize an earthquake and the shaking it produces at a site are described. These parameters are largely empirical, as a precise theoretical description is hampered by lack of detailed knowledge of the source mechanism and by the complexity of the propogation of the resulting seismic waves through the normally non-homogeneous geologic formations typical of the seismic region of the earth. The empirical approach to the problem is handicapped by the small number of recorded events, particularly large ones, upon which the data are based.

There are two terms which are commonly used to describe the size of an earthquake. These are "intensity" and "magnitude."

Earthquake Intensity - Intensity is an indication of an earthquake's apparent severity at a specific location, as determined by observers. It is a measure of the effects of an earthquake determined through interviews with persons in the quake area, damage surveys, and studies of earth movements. Consequently, intensity is a subjective measure of the size of an earthquake.

In the absence of any instrumental recordings of the ground motion, seismologists describe the severity of the ground shaking at a particular site by assigning an intensity number. The Modified Mercalli intensity scale is generally used in the United States to subjectively measure the effects of earthquake motion. This scale grades the effects into twelve classes ranging from I (ground motion not felt) to XII (nearly total damage). This scale is shown in Figure 8.

Intensity scales were used for the purpose of drawing seismic intensity maps which contain contour lines of equal seismic intensity. The Uniform Building Code seismic risk map is

MODIFIED MERCALLI INTENSITY SCALE

Intensity. A subjective measure of the force of an earthquake at a particular place as determined by its effects on persons, structures, and earth materials. The principal scale used in the United States today is the Modified Mercalli, 1956 version as defined below (modified from Richter, 1958, p. 137–138):

I. Not felt.

II. Felt by persons at rest, on upper floors, or favorably placed.

III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.

IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing automobiles rock. Windows, dishes, doors rattle. Wooden walls and frame may creak.

V. Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D[1] cracked.

VII. Difficult to stand. Noticed by drivers of automobiles. Hanging objects quiver. Furniture broken. Weak chimneys broken at roof line. Damage to masonry D, including cracks; fall of plaster, loose bricks, stones, tiles, and unbraced parapets. Small slides and caving in along sand or gravel banks. Large bells ring.

VIII. Steering of automobiles affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

IX. General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground and liquefaction.

X. Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.

XI. Rails bent greatly. Underground pipelines completely out of service.

XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown in the air.

1 See Uniform Building Code for specifications on quality of masonry construction.

FIGURE 8

MODIFIED MERCALLI SCALE

(taken from Nichols and Buchanan, circular 690, 1974)

determined largely from such intensity maps of past damaging earthquakes. It should be noted that because our recorded seismic history is short relative to earthquake recurrence intervals this method has serious limitations.

Earthquake Magnitude - Richter Magnitude is an arbitrary scale which gives a measure of the total amount of energy released by an earthquake as determined by measuring the maximum amplitude produced on a standard recording instrument. It is a measure of the absolute size of an earthquake, and does not consider the effect at any specific site location.

In 1935 C. F. Richter defined the magnitude, M, of an earthquake for shallow shock as

$$M = \log \frac{A}{10A_o}$$

where A is the maximum amplitude recorded by a Wood-Anderson seismograph at a distance of 100 kilometers from the disturbance, and A_o is an amplitude of one thousandth (0.001) of a millimeter. Observations at distances other than 100 km are corrected to the standard distance. Due to non-uniformities in the earth's crust, different fault orientation and other factors, M is not a precise measure of the size of an earthquake. For best results, an average value of M is determined from a number of recordings from different seismological stations.

There is no upper limit to the Richter Scale. However, since there is a physical limit to the amount of strain that rock can endure, it seems reasonable to postulate that there is an upper bound for the magnitude of an earthquake. In California, this is generally taken as 8.5.

Earthquakes of magnitudes 5.0 or greater can generate sufficient ground motion to be potentially damaging to structures. Design engineers are generally not concerned with earthquakes of a magnitude less than about 4.0 or 5.0, since they are of short duration and do not produce ground motion that causes serious damage to ordinary structures.

The relationship between the magnitude of an earthquake and the energy which it releases is generally given by the expression

$$\log E = 11.8 + 1.5 M$$

where M is the Richter magnitude and E is the energy in ergs.

It should be noted that the magnitude and energy releases are not related linearly. A difference of one unit in magnitude corresponds to a factor of 31.6 in the amount of energy released.

Consequently, an earthquake of magnitude 8 represents an energy release approximately 32 times greater than that of a magnitude 7 earthquake and about 1000 times greater than that of a magnitude 6 earthquake.

Magnitude and Surface Rupture Length

For most smaller earthquakes, below magnitude 6, the vertical and horizontal dimensions of the slipped fault area are believed to be the same order, but for large earthquakes the length of the slipped area may be measured in hundreds of miles, whereas the perpendicular dimension of California fault ruptures is thought to be at most 10 to 20 miles in extent. When plotting the length of ground surface rupture along the fault with respect to the magnitude of past earthquakes, considerable scatter is observed. However, as a whole, it can be said that the length of surface rupture increases with magnitude.

Housner (1969) has developed the following idealized relationship between the magnitude, M, and the length of surface rupture, L, in miles.

$$L = 1.82 \times 10^{-2} e^{M} \quad (M<6.3)$$

$$L = 2.25 \times 10^{-5} e^{2M} \quad (M>6.3)$$

This relationship is plotted on Figure 9 with data from several earthquakes having well defined ground rupture. Tocher (1958) and Greensfelder (1973) have proposed similar relationships for California and Nevada earthquakes as shown on Figure 9.

For engineering purposes, this idealized relation could be used to assign a maximum credible magnitude that might result from a fault of known length. Surface faulting in a particular earthquake generally extends over just a part of the total length of the pre-existing fault. Albee and Smith (1966) noted that the length of surface rupture accompanying historic earthquakes in Southern California has commonly been one-half to one-fifth the total length of the fault system on which the earthquake occurred. For analysis, it is necessary to make some assumptions as to the maximum length of fault that could reasonably be expected to slip in a single earthquake. This is generally taken as 50% of the total fault length and is related to the maximum credible earthquake. This value (50%) was used in assigning magnitudes to the various faults in Santa Barbara County, listed in Table 3, under the topic heading "Description of Individual Faults."

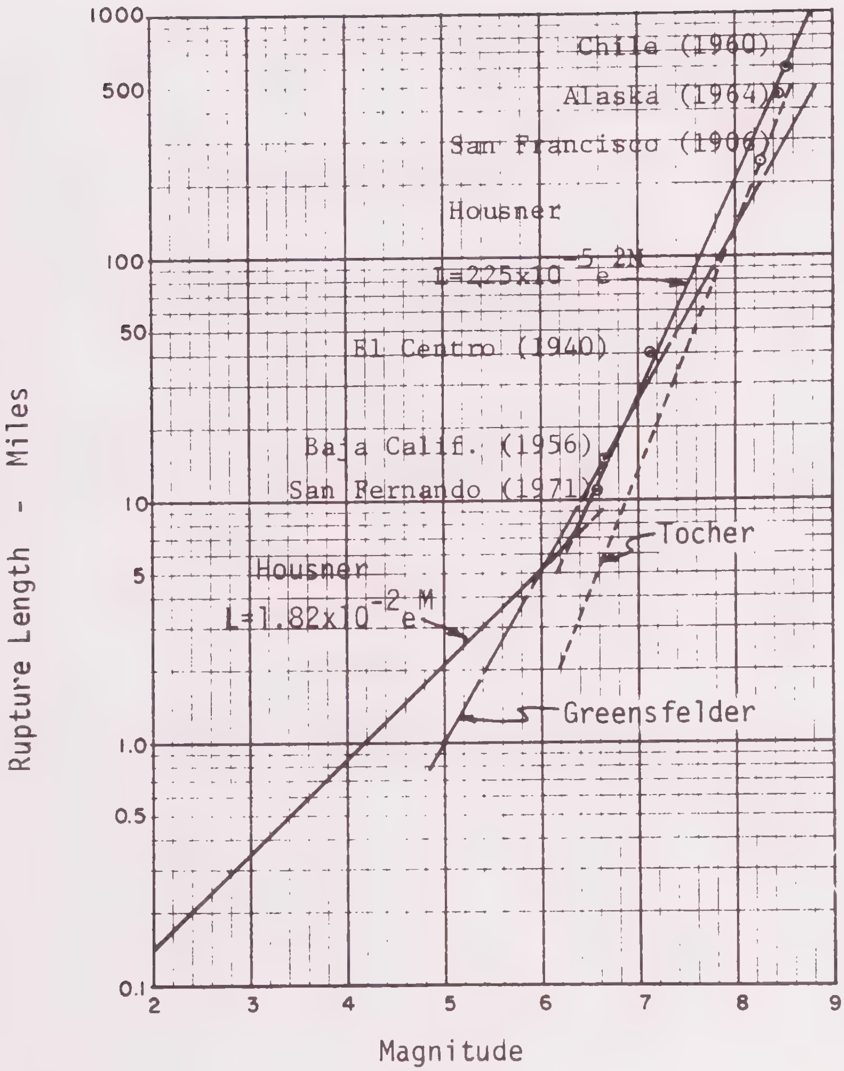


FIGURE 9

IDEALIZED RELATIONSHIP BETWEEN
FAULT RUPTURE LENGTH vs
MAGNITUDE OF EARTHQUAKE

(modified from Housner, 1969)

Earthquake Frequency

Since the lifetime of most engineered structures is limited to a few decades and since strong earthquakes are not an every day occurrence, it is important to learn about the frequency of earthquakes. Documented earthquake history is far too brief to permit reliable estimates of earthquake frequency on particular faults or in small regions. Consequently, it must be remembered when speaking of recurrence intervals or probability of occurence that the calculations must be based on a statistically significant sample of seismic events. Considering the limited period that we have been making suitable earthquake measurements (about forty years in California), it requires an area about the size of Southern California to provide a sufficient history of events for a seismically active region. Even an area of this size is not sufficient for calculating the probability of very large earthquakes.

However, the number of worldwide seismic events are statistically sufficient even for large magnitudes, so that their frequency of recurrence can be described by the equation

$$\log n = 7.7 - 0.9 M$$

where n is the mean annual frequency of a magnitude M earthquake. As shown on Figure 10, which shows a plot of world earthquakes, the curve deviates from a straight line relationship above magnitude 8, and the assumption is made that the line representing the relationship falls off asymptotically to a maximum value of magnitude 8.7.

Available data for a region including Southern California and northern Mexico (100,000 square miles) over a 29-year period indicate the frequency distribution for magnitudes between 3 and 6.5 follow the same form as the distribution of world earthquakes. Assuming that the same form of frequency distribution can be used for California earthquakes up to about 8.5, Housner (1970) calculated the probability of a seismic event producing an acceleration exceeding a specific value at least once during a specific period. The accelerations were based on earthquake magnitude and an idealized relationship of motion attenuation with distance. Curves representing Housner's calculations are shown on Figure 11 . Other calculations were made by Marachi and Dixon (1972) using past seismicity data for Southern California. Their results, which are shown in Figure 12, are approximately the same as Housner's. The basic assumption necessary to formulate these curves is that the occurrence of earthquakes within a region is random in time and in space, thus assuming that all portions of the region are equal in seismic

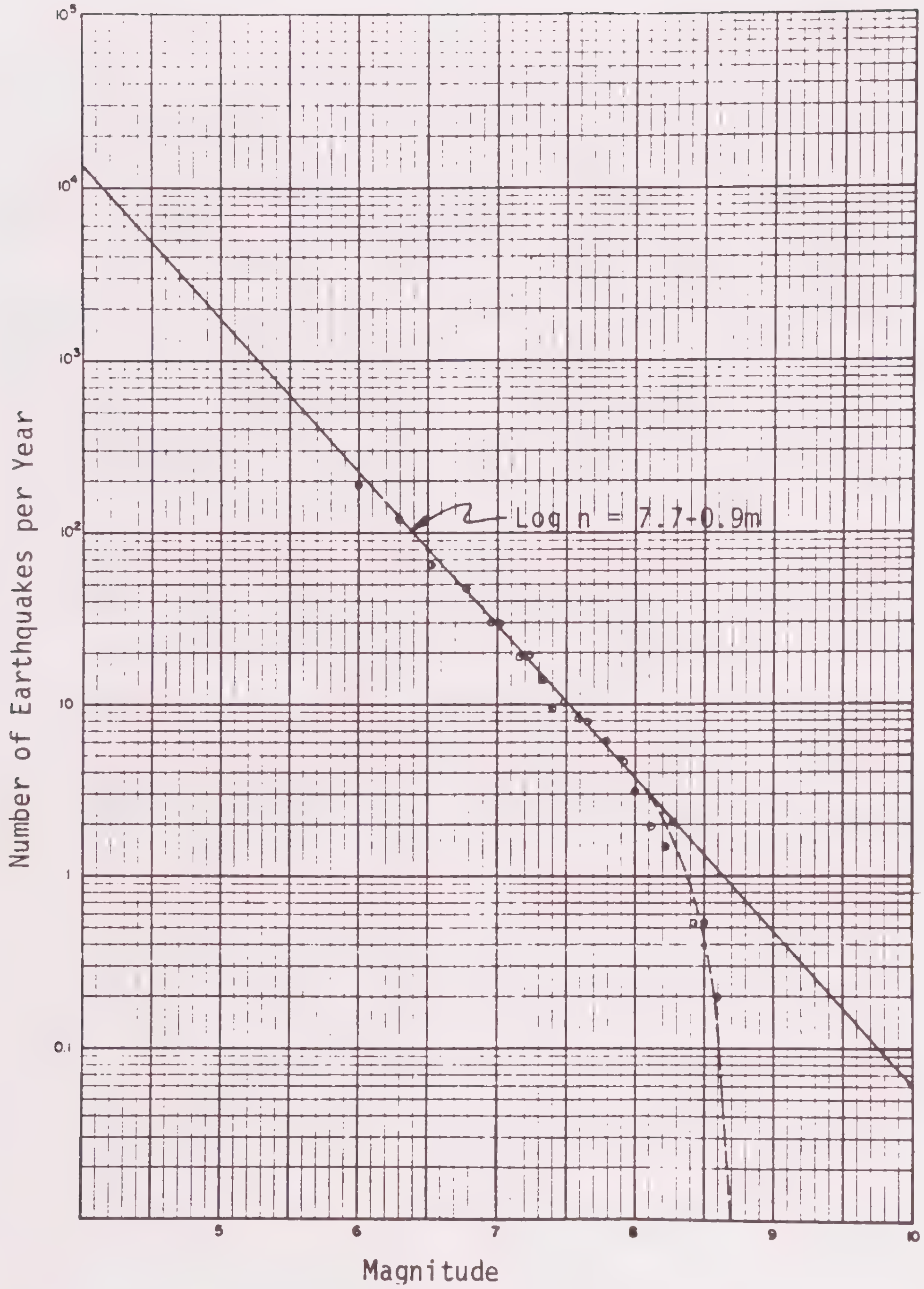
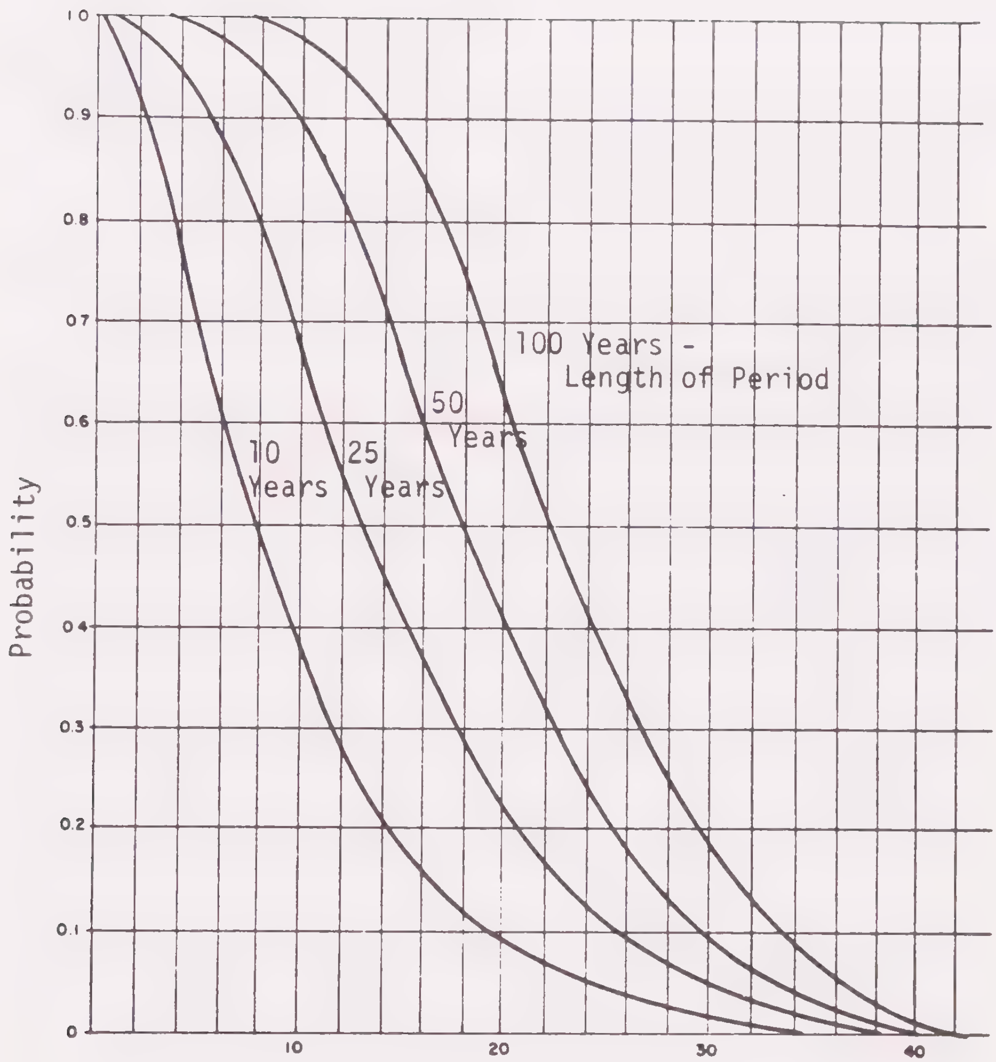


FIGURE 10

AVERAGE NUMBER OF WORLD EARTHQUAKES
PER YEAR DURING A 43-YEAR PERIOD

(from Housner, 1969)



Ground Acceleration (% g)

FIGURE 11

PROBABILITY OF ACCELERATION
EXCEEDING A SPECIFIC VALUE
AT LEAST ONCE DURING A SPECIFIED PERIOD

(from Housner, 1970)

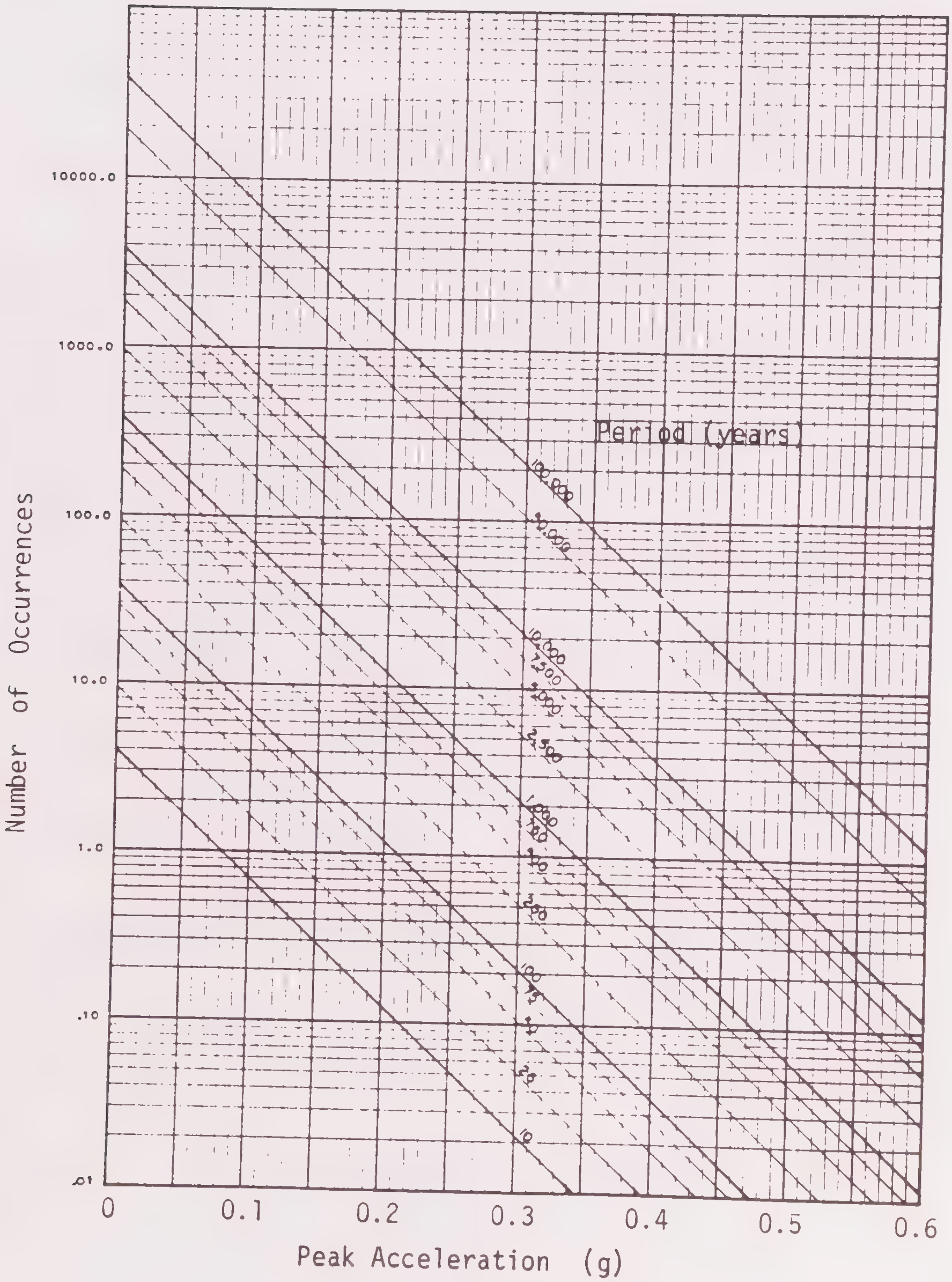


FIGURE 12

OCCURRENCES OF ACCELERATIONS IN SOUTHERN CALIFORNIA
(modified from Marachi and Dixon, 1972)

activity.

Even though the probability or return period of a seismic event at a particular site cannot be fully determined at the present time, use of the previous information in conjunction with reasonable judgment regarding the site's relative seismicity can give the design engineer a good "feel" for the likelihood of seismic activity during the expected lifetime of his structure.

Earthquake Recurrence Intervals

The seismic risk of a fault can be defined best by determining the long-term recurrence intervals (interval in years between earthquakes) of earthquakes with a given magnitude. The recurrence intervals are calculated on the basis of long-term slip rates of geologic units along the fault (Wallace, 1970; Clark, *et al*., 1972; Lamar *et al*., 1973). This approach can provide a basis for comparison of the earthquake risk of individual faults and has been used to estimate the recurrence intervals for major faults in southern California (Lamar *et al*., 1973). The results of such analyses for the San Andreas and Big Pine faults are shown in Table 2. As indicated in the descriptions of individual faults, data are not sufficient to determine the long-term slip rates of other active faults in Santa Barbara County. This is because of the difficulty in measuring and dating the offset of geologic units with sufficient accuracy.

Wallace (1970) presented the following equation for the recurrence interval at a given point on a fault:

$$R_x = D/S \qquad \text{Equation (1)}$$

Where R_x = recurrence interval at a point on the fault

D = displacement accompanying an earthquake (related empirically to Richter magnitude)

S = long-term rate of movement (from geodetic data or offset of geologic units)

This equation simply states that if elastic strain accumulating along a fault is typically released by earthquakes with displacement D, then the interval between such earthquakes (recurrence interval, R_x) will equal the displacement (D) divided by the long-term rate of movement (S).

The following assumptions are made: (1) Slip on faults occurs incrementally as sudden events which produce earthquakes. Slip will continue at the same rate as that determined by geodetic data and offset of geologic units. (2) Elastic strain accumu-

lates between earthquakes; the displacement during an earthquake represents the release of this accumulated elastic strain. It should be emphasized that the data are insufficient to verify these assumptions; the calculated recurrence intervals are only reasonable estimates based on present knowledge. For example, recurrence intervals determined by Equation (1) represent a long term average; there is, however, evidence of significant local (Ambraseys, 1970) and worldwide (Davies and Brune, 1971) time variations in the level of seismic activity.

For large earthquakes the distance from the causitive fault out to the limit of destructive earthquake accelerations is usually small relative to the total rupture length. Thus Equation (1) is adequate for assessing the earthquake hazard of a particular site. For engineering applications, where the fault to site distance is large relative to rupture length, and for comparison with the historic record of earthquakes, it is necessary to determine recurrence intervals over the entire length of the fault. Clark et al. (1972) used the following equation developed from Wallace (1970) to calculate recurrence intervals for the San Jacinto fault system:

$$R_t = \frac{R_x L}{L_t} \qquad \text{Equation (2)}$$

where: R_t = recurrence interval along a fault

R_x = recurrence interval at a point on the fault

L = length of fault rupture (related to Richter magnitude - see Figure 9)

L_t = total length of fault or fault segment for which recurrence interval is required

Estimation of Ground Motion Parameters

To an observer located within the zone of influence of an earthquake, the earthquake is characterized by a rapid series of vibratory ground displacements. Because of convenience in seismic and engineering studies, it has been desirable and customary to record the time history of the movement in terms of accelerations. It is this acceleration record or a suitable fabricated hypothetical acceleration record that is used in the latest type of seismic analysis and design.

A strong motion earthquake accelerogram is characterized in part by the intensity of accelerations, duration of strong shaking, and predominant natural period of the vibratory motion. These strong motion characteristics are a function of the particular

earthquake and the location of the recorder both with respect to the geological and soil conditions, and with respect to the source of the seismic waves. Thus, the major factors that appear to influence the type of earthquake motion felt at a particular site are the source mechanism, the propogation path characteristics, and the geologic and soil conditions at the site.

Some general statements that can be made with certainty from the current theory are useful in a qualitative understanding of earthquake ground motions.

1. The strength of the long period end of a ground motion spectrum increases with the length and depth of the fault break and its relative displacement.

2. The short period end of the spectrum which includes the peak acceleration depends more on the velocity of the fault displacement. The high accelerations in the Parkfield (1966) event illustrate this point. This "dislocation velocity" is itself dependent on the stress available to accelerate the surrounding rock once the fracture has started.

3. Higher frequency waves decay faster with distance than lower frequency waves.

4. Surface waves, which are more prevalent in alluvial deposits than in rock, decay less rapidly with distance than do body waves.

The following sections briefly summarize some of the techniques for determining these ground motion parameters with the greatest emphasis on maximum acceleration prediction, as most investigators have been concerned with this problem.

<u>Maximum Accelerations</u> - The severity of shaking at a particular site is most often measured by maximum or peak acceleration of the ground, even though velocity and displacement are more descriptive properties. Further, peak acceleration itself is not a particularly reliable measure of the strength of the acceleration record. It is to the overall strength of the record (rather than to an isolated peak) that structures respond. However, magnitude and peak acceleration are the best engineering measures commonly used at the present time. Also, as they have been in use for some time, they carry with them the benefits of engineering experience. However, it is expected that the source parameters, such as seismic movement, effective stress, and stress drop, will become the fundamental parameters in the estimation of potential ground shaking in earthquake engineering. These

parameters are physically related to the faulting process and to the resulting seismic radiation, and are presently the subject of intense research in strong motion seismology.

A number of investigators have proposed methods for determining bedrock or ground acceleration resulting from earthquakes. The previous investigations were reviewed by Seed, Idriss and Kiefer (1969) with the purpose of developing weighted average values applicable to California earthquakes. These results were summarized in a set of curves relating earthquake magnitude and distance from causative fault to the maximum bedrock acceleration.

Prior to the 1971 San Fernando earthquake, very few strong motions had been recorded within 25 miles of the causative fault. Simulation of strong motion rock accelerograms were generally based on strong motions recorded on soil deposits. Utilizing the records obtained in the San Fernando earthquake in conjunction with a 1-dimensional model and the assumption that all motion is propagated between the rock and soil surface in the form of vertically traveling, horizontally polarized, shear waves, Schnabel and Seed (1972) developed hypothetical rock motions from records obtained on soil deposits. Schnabel and Seed have produced attenuation curves for maximum bedrock accelerations. The curves, which relate maximum ground acceleration to distance from the causative fault as a function of earthquake magnitude, are shown on Figure 13. The Schnabel and Seed curves give higher estimates for the maximum rock acceleration than those of previous investigators (Seed, Idriss and Kiefer). Because it is generally believed that their analysis is based on the most current data, the Schnabel and Seed formulation is most often used to compute bedrock acceleration values.

Davenport (1972) studied the strong motion records from forty-six earthquakes and the results of underground nuclear explosions to determine a statistical relationship between ground acceleration, earthquake magnitude, and epicentral distance. His investigation determined the relationship:

$$a = 0.279\, e^{0.8M} R^{-1.64}$$

Where: a = the peak acceleration in terms of gravity
M = the earthquake magnitude
R = the focal distance in kilometers

This relationship is illustrated in Figure 14. For application to seismic zoning, it was determined that the acceleration

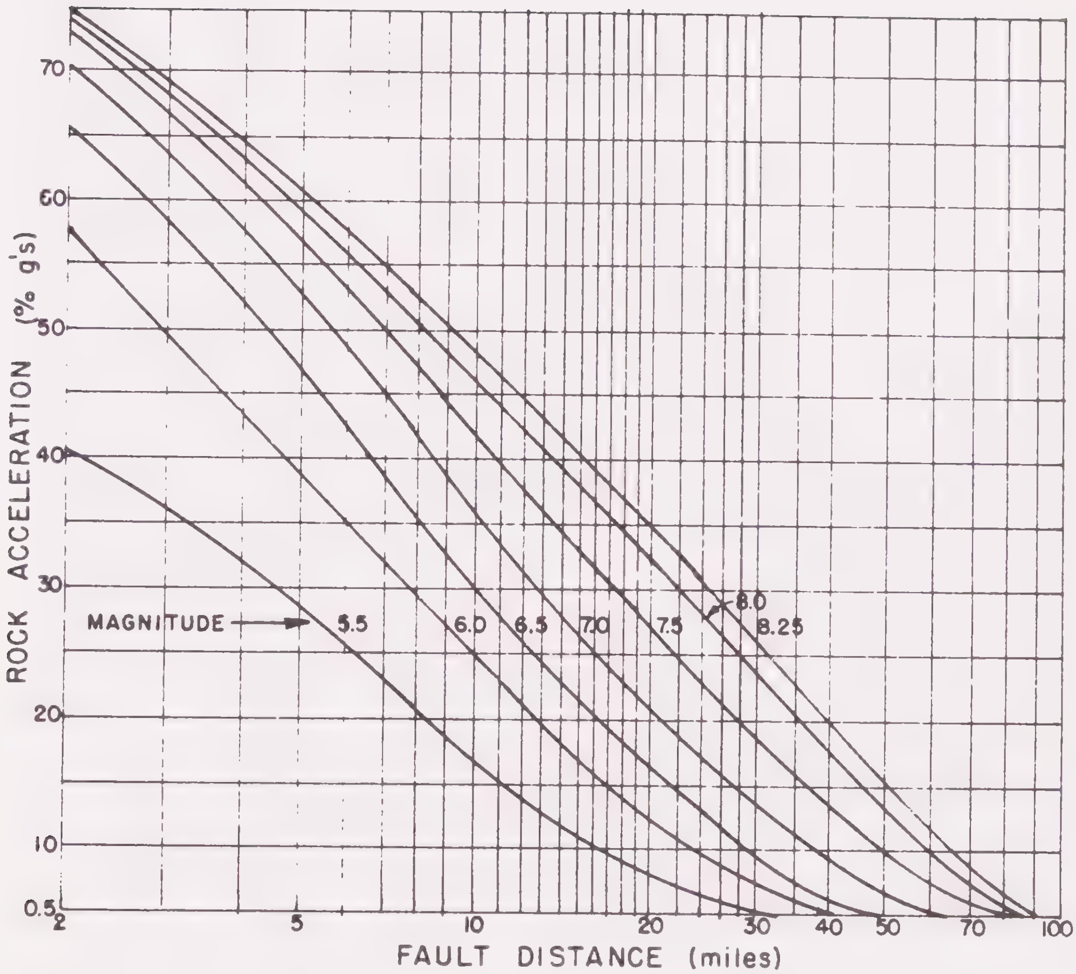


FIGURE 13

ROCK ACCELERATION vs FAULT DISTANCE
AND EARTHQUAKE MAGNITUDE

(from Schnabel and Seed, 1972)

corresponding to a given recurrence rate is augmented by an uncertainty factor of approximately 1.5. Since Davenport's analysis incorporates the most recent data and is considered to be best adapted for planning purposes, it will be used in the subsequent zoning determinations of this study.

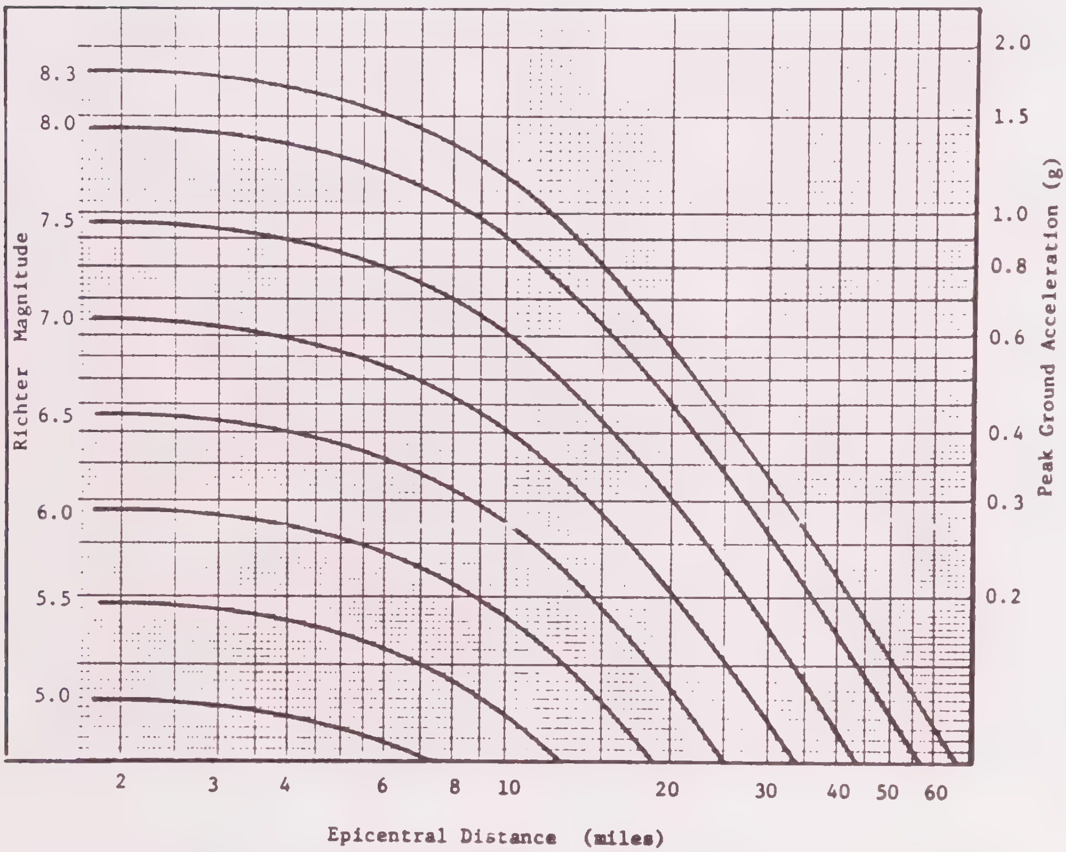


FIGURE 14

RELATIONSHIP BETWEEN EXPECTED
PEAK GROUND ACCELERATION,
EARTHQUAKE MAGNITUDE AND
DISTANCE FROM EPICENTER

(from Davenport, 1972)

Duration of Strong Shaking - The duration of strong shaking is an important characteristic of earthquake motion. Both experience and theory indicate that the duration of strong ground motion is generally related to the structural damage during an earthquake. The strong phase of shaking during the Parkfield earthquake of 1966 lasted only about 1.5 seconds, with a maximum acceleration of 0.5 g, and very little damage occurred. However, the Taft (1952) and El Centro (1940) earthquakes with lower accelerations, but a duration of strong shaking near twenty seconds resulted in considerable damage.

The duration of strong shaking has not been rigorously defined, and the determination of this parameter probably depends on the investigator. The general trend is that duration increases with magnitude and also with distance from the epicenter due to wave scattering and dispersion. Two possible criteria to be used are: (1) the time interval between the first and last acceleration peak which was greater than 0.05 g, and (2) the time interval between the first and last peak which was greater than 25 - 30% of the maximum acceleration.

Housner's (1965) recommended relation between the duration of strong shaking and earthquake magnitude is shown on Figure 15. This estimation is based on several past strong motion records and is a subjective determination of the duration as presumed applicable to engineering studies. The low intensity earthquake motions at the end of large earthquakes or the low intensity vibrations associated with earthquakes of magnitude less than about 4 were not included.

The U. S. Geological Survey seismic design criteria for the Alaskan pipeline (1972) include a relationship between magnitude and strong motion duration. For comparison, this is also shown on Figure 15.

Predominant Periods - The predominant period reflects the frequency content of the ground motion and it is presently defined as the period at which the acceleration response spectrum reaches a maximum. It should be understood that the assigning of a predominant period to an earthquake record does not imply that the strength of the record is confined to a narrow range about that period. Except in very rare circumstances, the record strength is spread over one or several broad bands whose center can be approximately characterized by the peak acceleration response spectrum value. Two basic studies have attempted to assess the predominant periods of rock accelerations. Gutenberg and Richter (1956) presented data for the predominant periods of accelerations developed, at different epicentral distances, by

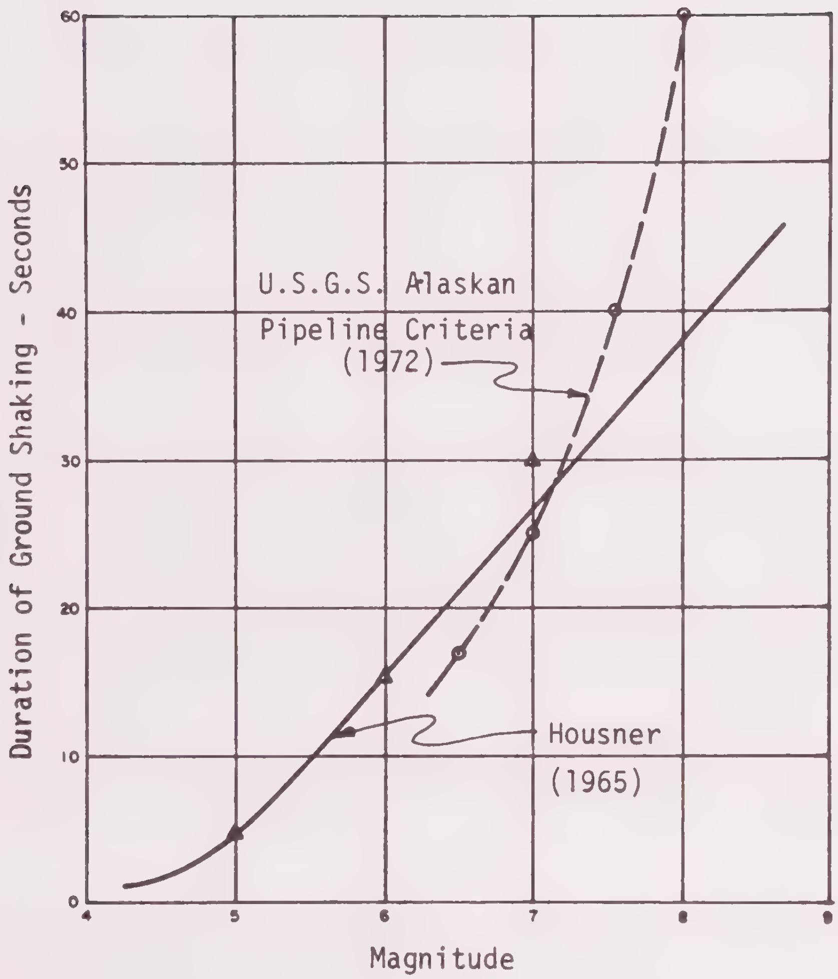


FIGURE 15

DURATION OF STRONG
MOTION EARTHQUAKES

(modified from Housner, 1965)

earthquakes with magnitudes ranging from 5.5 to 6.5. Predominant periods for accelerations in rock at different epicentral distances for earthquakes with magnitudes greater than 7 were presented by Figueroa (1960). Comparison of the relationships showed that the predominant period, for any epicentral distance, increases with magnitude. Also the predominant period generally increases with the distance from the energy source. Both trends can be predicted by theoretical arguments. By interpolation and minor extrapolation, Seed, Idriss, and Kiefer (1969) presented what they believe to be reasonable average values for assessing predominant periods for a wide range of magnitudes and distances to the causative fault. These values are presented on Figure 16. Due to the scatter of original data, some deviation from these average values, as with other values presented for determination of ground motion parameters, should clearly be expected.

The Design Earthquake

As previously mentioned, the acceleration record of a seismic event, or response spectra derived from it, is the necessary starting point in contemporary seismic analysis and design. Since the chances of having available an earthquake record of the exact specifications required for design are extremely remote, it is necessary to formulate or fabricate a suitable hypothetical design earthquake.

The general earthquake data described in the previous sections and predetermined geologic and soils information can be utilized to estimate ground motions expected at a site under consideration. The expected magnitude for faults that are considered to have a possible effect on the site should first be determined. Then, knowing the expected magnitude and the distance from the site to the fault, ground motion parameters can be estimated. With the essential design features of the strong motion accelerogram determined, the design accelerogram can be formulated by modifying an existing accelerogram from a similar earthquake or an appropriate artificial accelerogram, such as one described by Housner et al (1968). After an accelerogram has been selected and the maximum amplitude adjusted by a scale factor, the time scale is also multiplied by an appropriate factor to change the predominant period to the desired design value. If the duration of strong shaking in the selected accelerogram is not about the same as the required duration, it can be changed by adding or repeating a small portion of the motion toward the end, or by cutting a portion of the accelerogram as appropriate.

When performing a dynamic analysis of a structure either the equations of motion of the structure can be integrated directly

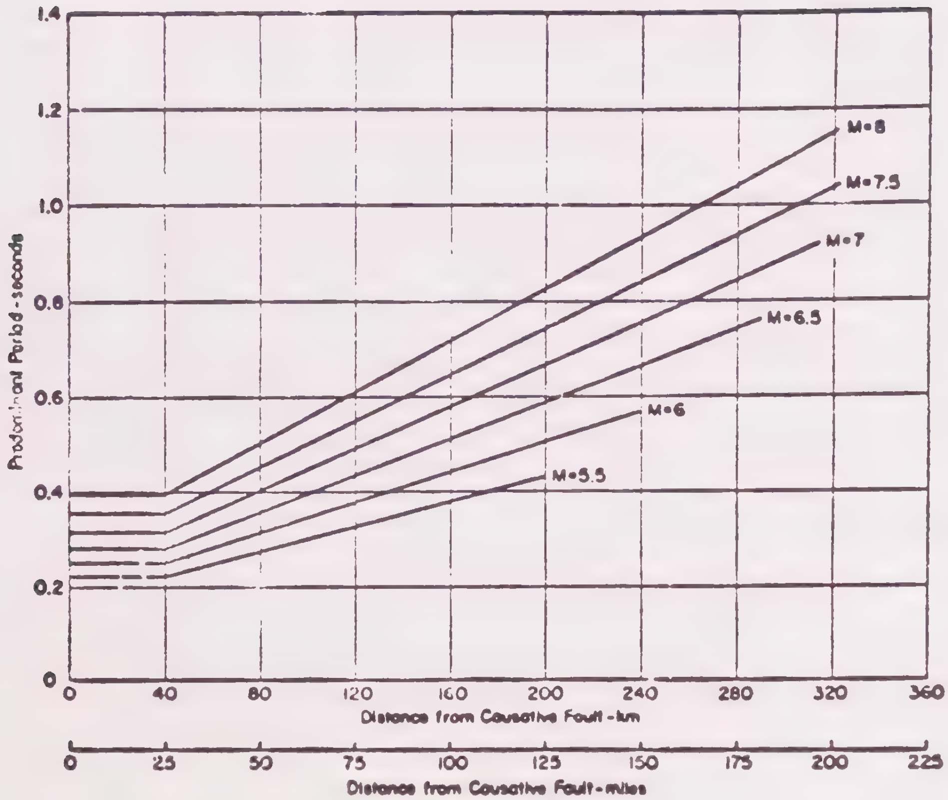


FIGURE 16

PREDOMINANT PERIODS FOR
MAXIMUM ACCELERATIONS IN ROCK

(from Seed, Idriss and Kiefer, 1969)

for the particular design accelerogram, or the time histories of the design earthquake can be used to compute response spectra from which the maximum modal responses may be determined and combined in some approximate manner. The response spectrum for a specific earthquake record gives the peak response of a single degree of freedom linear oscillator, plotted as a function of the oscillator's natural period and damping when the oscillator is subjected to shaking given by that record.

Because of the random nature of earthquake records, different records with the same values of the general characteristics described above can produce responses in the structure differing by 50% or more (see Adu, 1971). Hence, for more important structures, it is usual to perform analyses using several different input earthquakes.

SEISMICITY OF SANTA BARBARA COUNTY

Regional Geologic Structure

A knowledge of the regional geologic structure is helpful in understanding the earthquake risk of individual faults. The Transverse Ranges Province of Southern California trends east-west, transverse to the northwest-southeast trend of the adjacent Coast Ranges, San Joaquin Valley, and Sierra Nevada Provinces to the north, and the Peninsular Ranges Province to the south. The east-west trending physiographic features in the southern portion of Santa Barbara County lie at the western end of the Transverse Ranges Province, whereas the northwest trending features in the northern part of the County are included in the Coast Ranges Province.

The orientation of the physiographic features is a reflection of the regional geologic structure. Within the Coast Ranges the northwest trending San Andreas and Nacimiento faults and other subparallel faults are the main structural features (see Seismic Tectonic Map). Within the Transverse Ranges the San Andreas fault has a nearly east-west trend and other important faults trend east-west to northeast.

It has been suggested that California lies astride the juncture of two relatively rigid plates of the earth's crust that are sliding past each other in response to movement of subcrustal material (Atwater, 1970). The main surface trace of this juncture is the San Andreas fault. The same forces which are acting to move northward that portion of California on the western side of the San Andreas fault apparently result in a number of other important faults with the same northwest trend. In the southern Coast Range Province within Santa Barbara County these include the Nacimiento, Ozena, Suey, and Little Pine faults; the San Andreas fault is situated 7 miles northeast of Santa Barbara County.

Most of the recorded earthquakes and historic fault breaks in California have occurred as a result of rupture along faults in the San Andreas set of northwest trending faults; this suggests that most of the accumulating strain energy is being released along these breaks. Important exceptions in the Transverse Ranges include movement on an east-west trending fault beneath Santa Barbara Channel, which may have caused the 1925 Santa Barbara earthquake, movement on the Big Pine fault in 1852 during a large earthquake, and movement on the Santa Monica fault system during the Point Mugu earthquake of February 21, 1973 (Ellsworth et al., 1973).

It has been suggested (Anderson 1971) that faults in the Transverse Ranges are produced by north-south compression relative to the major horizontal movement on the San Andreas fault. The east-west bend in the San Andreas fault as it passes through the Transverse Ranges tends to obstruct the principal regional motion, this produces compressional forces which are translated into uplift, along with a component of horizontal movement, of the Transverse Ranges along east-west trending faults. If the east-west trending faults in the Transverse Ranges are only secondarily related to the major regional motion on the San Andreas fault as appears to be the case, this would explain why the earthquakes occurring along such east-west faults have historically been less frequent and less intensive.

General Seismicity

Earthquake risk in any region can be estimated usefully only by combining (1) geological studies identifying active faults, and (2) historical or instrumental records, resulting in catalogs of known occurrences of earthquakes. All historic fault movement in California has taken place on pre-existing faults. Furthermore, movement has always - or nearly always - taken place on faults for which there is evidence of geologically recent movement. In other words, the more recent the movement, the more likely future movement will occur.

It should be kept in mind that for every "active" or "potentially" active fault there are probably a thousand inactive faults, so a fault should not automatically be considered a hazard.

In regard to the second method of estimating earthquake risk, the entire known history of California earthquakes now extends only a little over two centuries. This is an extremely short time in the history of the earth, and even if our catalogs of earthquakes were complete for that interval, it is unlikely that they would give an adequate picture of the possibilities. For the earlier 150 years, we can list only the larger shocks with any pretense to completeness; to these are added a more or less haphazard sample of smaller earthquakes which have centered near enough to populated localities to attract attention.

Seismographs sufficiently sensitive to register the larger earthquakes in Southern California were installed at Berkeley and Mount Hamilton (Lick Observatory) in 1911. On many occasions, their recordings gave useful information bearing on the magnitudes of such events; but they were not sufficient for accurate determination of the corresponding epicenters.

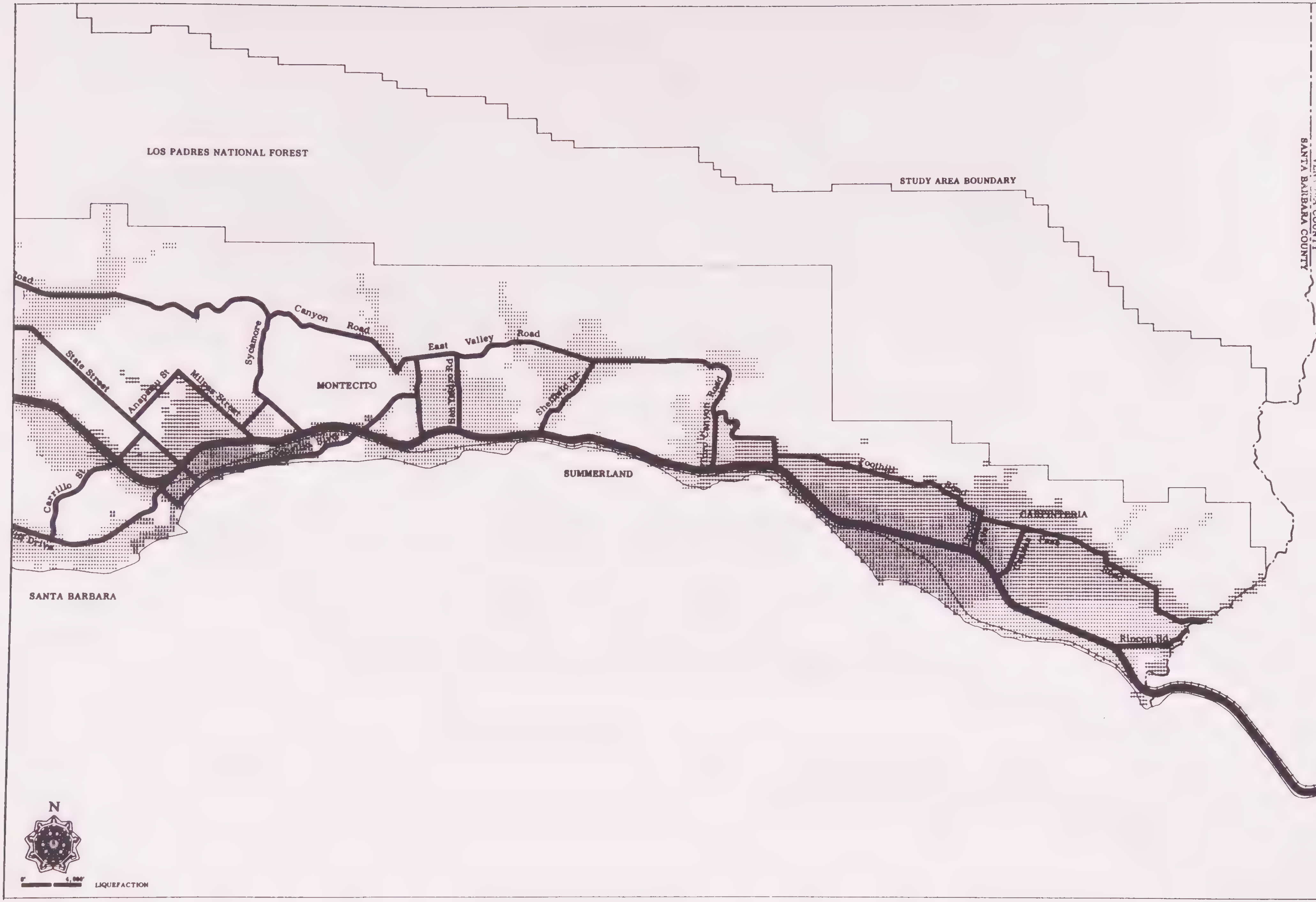
Santa Barbara County
Liquefaction

Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	2. +1 (High)
2. Moderate	6. ±1 (Low, High)

Twitchell Reservoir
SANTA MARIA RIVER
GUADALUPE
SANTA MARIA
POINT SAL
ORCUTT
CASMALIA
GAREY
SISQUOC
SISQUOC RIVER
State Route 166
CUYAMA RIVER
NEW CUYAMA
CUYAMA
SAN LUIS OBISPO COUNTY
KERN COUNTY
VENTUCOPA
Zaca Lake
LOS PADRES NATIONAL FOREST
PURISIMA POINT
VANDENBERG AIR FORCE BASE
LOS ALAMOS
Highway 101
SURF
SANTA RITA
LOS OLIVOS
BALLARD
BUELLTON
SOLVANG
SANTA YNEZ
State Route 154
State Route 1
POINT ARGUELLO
SANTA YNEZ RIVER
VENTURA COUNTY
LAS CRUCES
GAVIOTA
POINT CONCEPTION
MONTECITO
Foothill Rd
East Valley Rd
CARPINTERIA
SUMMERLAND
GOLETA
Cliff Dr
SANTA BARBARA
N

South Coast Study Area~East
Liquefaction

Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	2. +1 (High)
2. Moderate	6. ±1 (Low, High)



LOS PADRES NATIONAL FOREST
STUDY AREA BOUNDARY
VENTURA COUNTY
SANTA BARBARA COUNTY
Canyon Road
East Valley Road
Sycamore
State Street
Anapamu St
Milpas Street
MONTECITO
Sheffield Dr.
Carrillo St
SUMMERLAND
Foothill Blvd
CARPINTERIA
Rincon Rd
SANTA BARBARA
N
0'
4,000'
LIQUEFACTION

South Coast Study Area ~ West
Liquefaction

	Problem Rating	Possible Variation from Assigned Rating
	1. Low	1. No Variation
	1. Low	2. +1 (Moderate)
	1. Low	4. +2 (High)
	2. Moderate	2. +1 (High)
	2. Moderate	6. ±1 (Low, High)

LIQUEFACTION

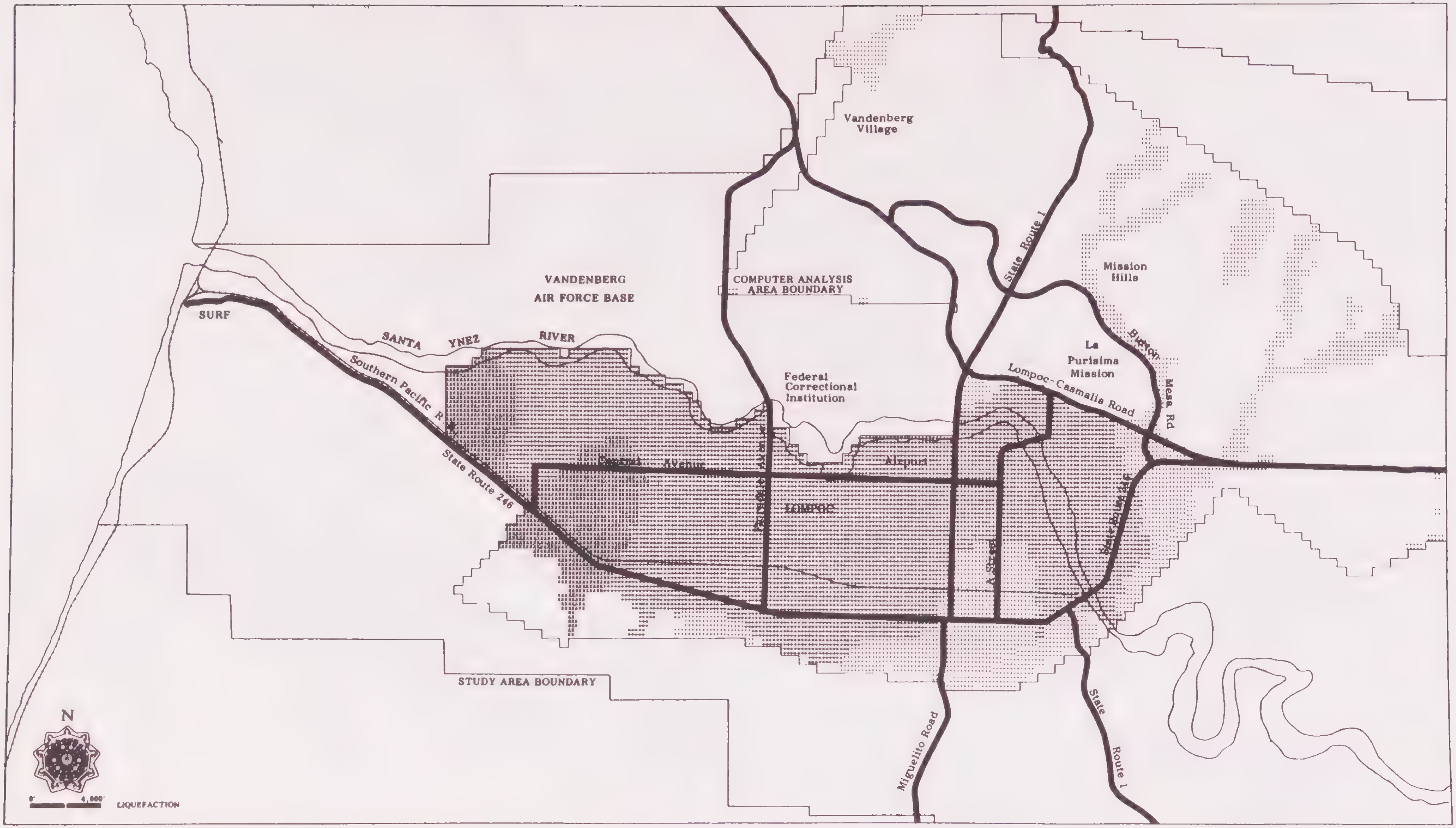
Santa Ynez Valley Study Area
Liquefaction

Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	2. +1 (High)
2. Moderate	6. ±1 (Low, High)


COMPUTER ANALYSIS AREA BOUNDARY
STUDY AREA BOUNDARY
LOS OLIVOS
U.S. HIGHWAY 101
BALLARD
Avenue
Refugio Road
Edison St
SANTA YNEZ
BUELLTON
SOLVANG
Route 246
Airport
SANTA YNEZ RIVER
Alisal Road
N
0'
4,000'
LIQUEFACTION

Lompoc Study Area
Liquefaction

Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	2. +1 (High)
2. Moderate	6. ±1 (Low, High)



Vandenberg
Village
VANDENBERG
AIR FORCE BASE
COMPUTER ANALYSIS
AREA BOUNDARY
Mission
Hills
SURF
SANTA
YNEZ
RIVER
La
Purisima
Mission
Federal
Correctional
Institution
Lompoc-Casmalia Road
Mesa Rd
Southern Pacific R
State Route 246
State Route 1
Airport
LOMPOC
A Street
STUDY AREA BOUNDARY
Miguelito Road
State
Route 1
N
0'
4,000'
LIQUEFACTION

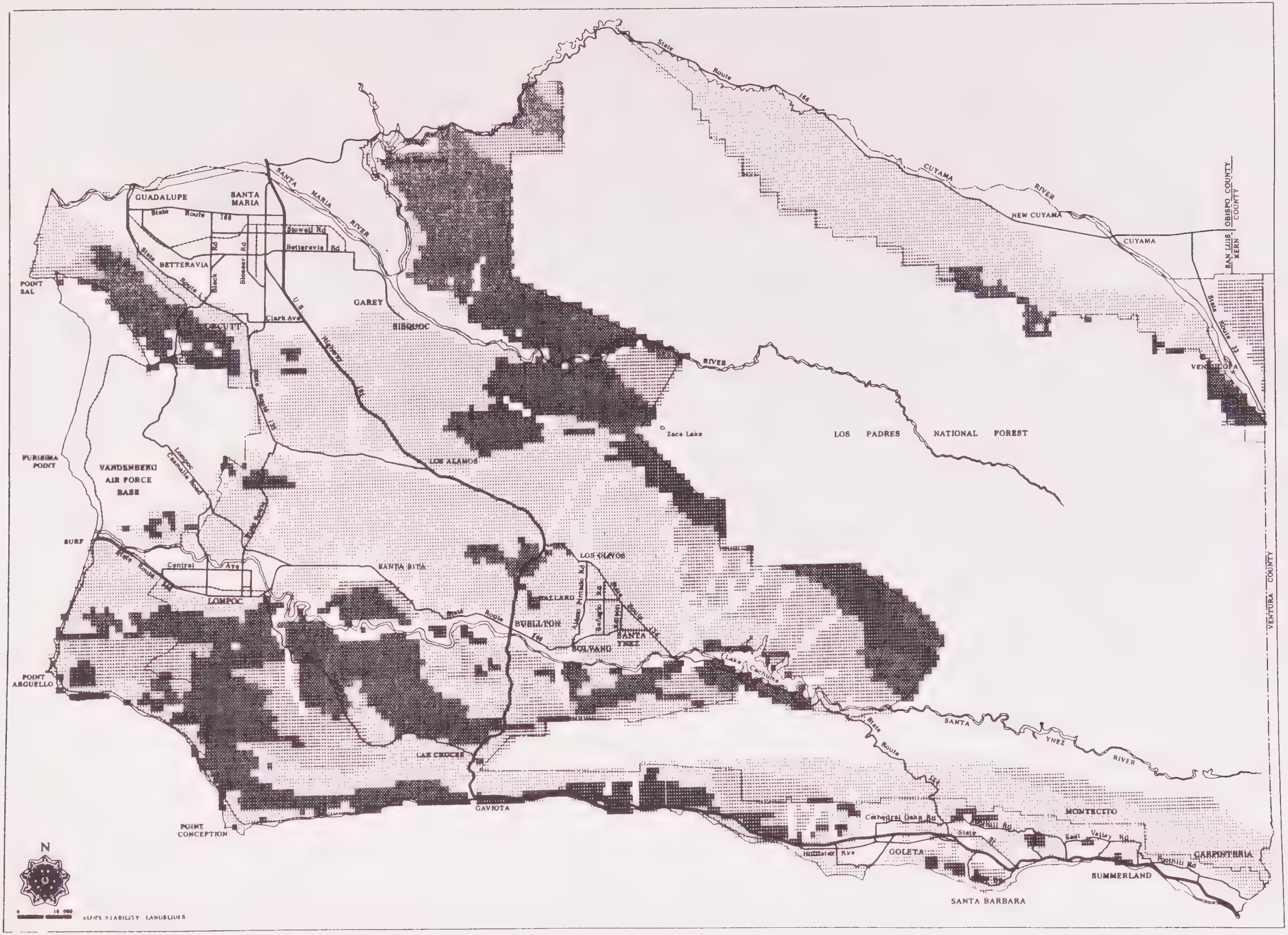
Santa Maria-Orcutt Study Area
Liquefaction

	Problem Rating	Possible Variation from Assigned Rating
	1. Low	1. No Variation
	1. Low	2. +1 (Moderate)
	1. Low	4. +2 (High)
	2. Moderate	2. +1 (High)
	2. Moderate	6. ±1 (Low, High)

SAN LUIS OBISPO COUNTY
SANTA BARBARA COUNTY
SANTA MARIA RIVER
GUADALUPE
SANTA MARIA
State Route 166
COMPUTER ANALYSIS AREA BOUNDARY
Stowell Road
Santa Maria Valley R. R.
Black Road
Blosser Road
Betteravia Road
STUDY AREA BOUNDARY
Mahoney Rd.
BETTERAVIA
POINT SAL
Point Sal Beach State Park
State Route 1
Santa Maria Airport
State Route 135
U.S. HIGHWAY 101
Clark Avenue
ORCUTT
VANDENBERG AIR FORCE BASE
Southern Pacific R.R.
CASMALIA
N
LIQUEFACTION

Santa Barbara County
Slope Stability, Landslides

Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	4. +2 (High)
2. Moderate	6. ±1 (Low, High)
3. High	5. -2 (Low)
3. High	3. -1 (Moderate)



SLOPE STABILITY LANDSLIDES

South Coast Study Area ~East
Slope Stability, Landslides

Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	3. -1 (Low)
2. Moderate	2. +1 (High)
2. Moderate	6. ±1 (Low, High)
3. High	3. -1 (Moderate)
3. High	1. No Variation

SLOPE STABILITY, LANDSLIDES

South Coast Study Area ~West
Slope Stability, Landslides

	Problem Rating	Possible Variation from Assigned Rating
	1. Low	1. No Variation
	1. Low	2. +1 (Moderate)
	1. Low	4. +2 (High)
	2. Moderate	3. -1 (Low)
	2. Moderate	2. +1 (High)
	2. Moderate	6. ±1 (Low, High)
	3. High	3. -1 (Moderate)
	3. High	1. No Variation

SLOPE STABILITY, LANDSLIDES

Santa Ynez Valley Study Area
Slope Stability, Landslides

Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	3. -1 (Low)
2. Moderate	2. +1 (High)
2. Moderate	6. ±1 (Low, High)
3. High	5. -2 (Low)
3. High	3. -1 (Moderate)

Sensitive seismographs began regularly recording at Pasadena in 1923; in subsequent years, others were added, one of which began recording at the Santa Barbara Museum of Natural History in July, 1927. This program, begun under the Carnegie Institution of Washington and later transferred to the California Institute of Technology, has resulted in an increasingly complete listing of the smaller shocks of the area, with their associated ratings on the magnitude scale. A new network of seismograph stations surrounding the Santa Barbara Channel region was installed by the U.S.G.S. in 1969 to augment the CIT stations. (See plot of seismograph stations on Figure 17). This greatly improves the accuracy of locating seismic shocks in Santa Barbara County.

It was originally hoped that the smaller earthquakes would prove to be associated chiefly with the main active faults, and perhaps that a local increase in small activity might serve as warning of a large event in preparation. Such expectations have largely been disappointing. Long segments of major faults, such as the San Andreas fault, which are historically known to have been the seat of large earthquakes, have shown nearly complete quiescence in the last 50 years; while other localities, characterized by frequent small earthquakes, have not been subjected to larger ones. The epicenters of small earthquakes, as determined from the seismograph recordings, show little or no disposition to align in a manner to identify an active fault - except when they are aftershocks of a previous large one, and serve then to indicate the linear extent of faulting which presumably occurred in the main event.

Foreshocks occur; that is, a large earthquake may be preceded by a few minutes, hours, or days, by a shock which proves to have nearly the same epicenter. Unfortunately, until after the main event, there is nothing to distinguish such a foreshock from the ordinary small shocks which are always occurring scattered over the entire region.

There is at present much interest in new evidence that a measurable change in the speed of seismic waves may take place in an area where a large earthquake is in preparation. This possibility is being followed up vigorously, and new seismograph stations are being set up for this purpose. It is as yet too early to expect any definite results.

The incompleteness of information supplied by historical and seismographic data is partly compensated by the results of geological field work. The principal faults can be located, and, in favorable circumstances, the geologist may be able to decide whether or not a given fault is active - in the sense of being a

potential source of strong earthquakes - independently of the known occurrence of such shocks.

Correlation of observed earthquakes with specific faults is often difficult. Historical accounts of the usual sort can, at most, establish a presumption that this or that known fault is responsible. Exceptions occur only on the rare occasions when actual fault displacement has been observed and described as was the case along the San Andreas fault in 1857.

Epicenters located by the use of seismographs have usually been subject to uncertainties of several miles. Unfortunately, much of Santa Barbara County is unfavorably located with respect to seismograph stations, and errors of ten to fifteen miles are possible. Consequently, there is often doubt as to which of several known faults a given recorded earthquake should be ascribed.

Search for active faults is now going on more vigorously than in the past; but it is certain that especially in the less populated areas, our information is far from complete. Moreover, some earthquakes originating offshore are large enough to cause damage on land. One such example is the major earthquake of 1927, off Point Arguello. Another may be the earthquake of 1812, suspected of having originated under the Santa Barbara Channel. In recent years, earthquakes of a wide range of magnitude have been located reliably with epicenters in the Channel; its waters probably cover a highly active geologic structure, possibly with more than one major fault. (See Figure 18 after Lee and Vedder, 1973).

A brief description of the most significant quakes affecting Santa Barbara County is given in a separate section. Review of this alone leads to some well-defined conclusions. In Santa Barbara County, as indeed in most of Southern California, there is one seismic event which chiefly determines the requirements for design of buildings and other structures to resist earthquakes. This is the likelihood of another event on the San Andreas fault comparable with that of 1857. We do not have as much detailed information on the effects in 1857 as we should like, but on the whole, they are comparable, in terms of intensity and geographical extent, with those of the 1906 earthquake centered farther north on the San Andreas fault. With this in mind, seismologists and engineers can envision the degree of earth shaking to be expected at given distances from the San Andreas fault. Ground shaking would be quite strong, usually exceeding what might be expected in earthquakes with other probable epicenters and magnitudes. Generally speaking, a structure designed to survive a repetition of the 1857 earthquake might be expected to withstand any other similar event.

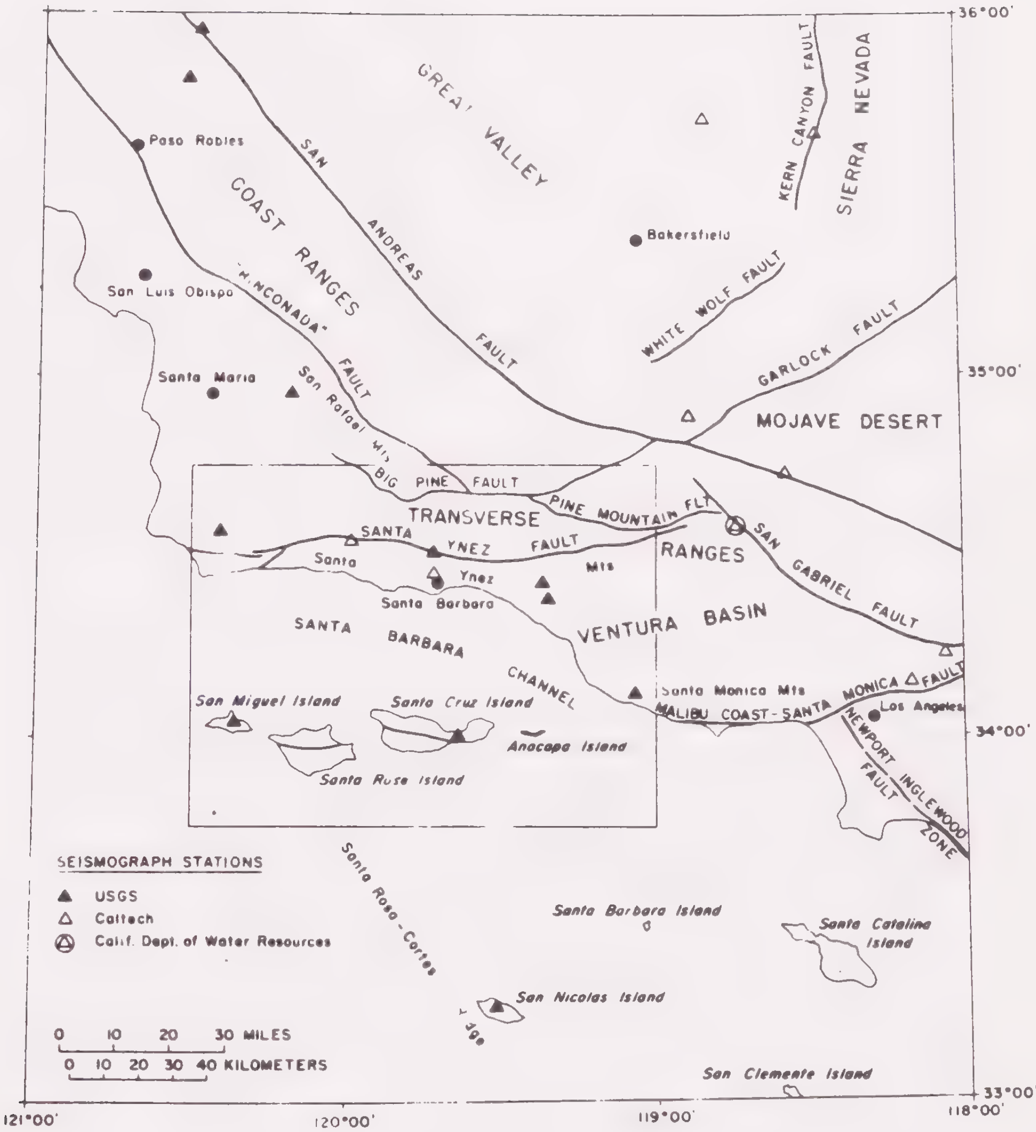


FIGURE 17

INDEX MAP SHOWING LOCATION OF SEISMOGRAPH STATIONS IN SANTA BARBARA CHANNEL AND VICINITY (from Lee and Vedder, 1973)

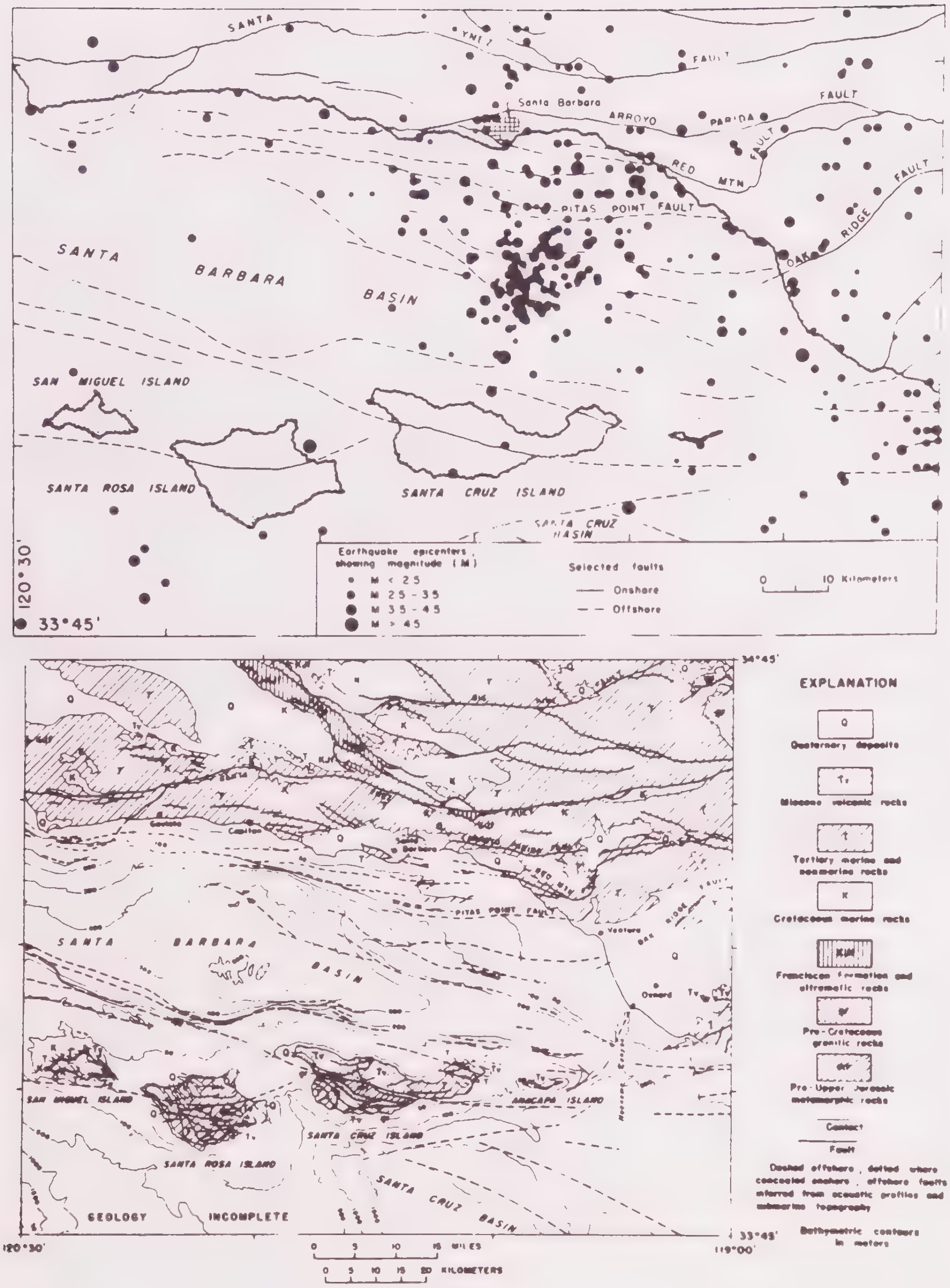


FIGURE 18

EARTHQUAKE EPICENTERS AND GENERALIZED GEOLOGIC MAP OF SANTA BARBARA CHANNEL (from Lee and Vedder, 1973)

However, this conclusion must be qualified, and we cannot be sure to what extent. For example, the Mission at Santa Barbara was not damaged in 1857, although there was damage to houses in the town; but the earthquake of 1812 damaged the Mission church so that it had to be rebuilt. We would like to take into account the effects of the 1812 event as systematically as for 1857; but we are extremely uncertain as to where it originated. We can, of course, note that it was seriously damaging at Santa Ynez Mission, and destructive at Purisima (near Lompoc); so those particular places may be exposed to strong earthquakes in the future. Lompoc, indeed, has been shaken several times with varying degrees of damage.

Occurrence of earthquakes damaging at Los Alamos in both 1902 and 1915 renders that locality a likely site for future strong shaking.

Several damaging earthquakes have originated near the north shore of the Santa Barbara Channel, from Santa Barbara to Oxnard.

If, as seems probable, the earthquake of 1852 originated on the Big Pine fault, that adds to the probabilities of heavy shaking in the northern part of the County.

Another speculative source for a very large earthquake is the Nacimiento fault, and other faults associated with it. These lie largely outside of the County, and probably represent no appreciable risk beyond that due to the San Andreas fault.

A summary of historic fault movement in Santa Barbara and topographic evidence for Recent (0 - 11,000 years) fault displacement is shown in Table 1.

SUMMARY OF HISTORIC FAULT MOVEMENT AND TOPOGRAPHIC EVIDENCE FOR HOLOCENE (0 - 11,000 YEARS OLD) FAULT DISPLACEMENT

Fault	A	B	C	D	E	F	G
San Andreas	1857				√	√	√
Graveyard-Turkey Trap					√		
Nacimiento					√	√	√
Lion's Head				0.7			
Big Pine	1852	7±	R		√		√
Santa Ynez	1927?	7.3		0.8	√	√	√
Pacifico	1927?	7.3				√	
Red Mountain	1941?	6.0		1.3-2.0			
Mesa			C?	2.1	?		
More Ranch					√		
Santa Cruz Island							√
Santa Rosa							√

Historic Evidence

A Year of historic earthquake, querried if earthquake occurred on possible sub sea extension of fault

B Magnitude of historic earthquake

C Ground rupture (R) during historic earthquake or creep (C)

D Elevation change in centimeters across fault on level lines surveyed 1957-60 and 1971; data from Willott (1972)

Topographic Evidence

E Geologically Recent fault scarps

F Sag ponds

G Drainage offset

√ Means item applies to particular fault; no data if blank.

TABLE I

Condensed Seismic History

The chronicle of earthquakes felt or causing damage in Santa Barbara County now extends over nearly two centuries; but this is too short a time, geologically speaking, to provide a reliable sample of the possibilities. Moreover, in the earlier years, our information was derived chiefly from the Mission chronicles, and consequently can be inclusive only for the few relatively large events.

Fairly complete lists of the known occurrences may be found in the seismic catalogs of Holden and of Townley and Allen, down to their closing dates; but almost all the earthquakes likely to be of significance are listed in the U. S. Department of Commerce, "Earthquake History of the United States," revised to 1970.

The entries which follow represent those earthquakes which seem of most value in establishing the extent and geological distribution of the known seismicity and in relating them to known or suspected faults and geologic structures.

<u>1769, July 28</u> - Of interest here only as being the earliest definitely dated California earthquake. It was felt strongly by the pioneer exploring expedition of Portola when in camp on the Santa Ana River. This might really have been a major earthquake, in which case it would have been perceptible to some extent in the present area of Santa Barbara County.

<u>1800</u> - The earliest reported earthquake felt in Santa Barbara.

<u>1806, March 24</u> - Felt at Santa Barbara. Walls of the Mission chapel were cracked.

<u>1812, December 8</u> - This earthquake wrecked part of the Mission at San Juan Capistrano, and did some damage to San Gabriel Mission. Its effects probably did not extend much farther west. Early historians sometimes confused this earthquake with the December 21st quake.

<u>1812, December 21</u> - The damaging effects of this major earthquake increased from San Fernando westward. There was much damage at Santa Barbara, and the church was rebuilt soon after. At Santa Ynez, some of the structures were destroyed and never replaced. At Purisima (near Lompoc), much of the installation was wrecked; the site was abandoned, and replaced by buildings elsewhere.

This earthquake may have been accompanied by a wave of tsunami type, probably of only moderate height, on the coast of the Santa Barbara Channel (see discussion in the section on tsunamis).

Santa Barbara County Seismic-Tectonic Map

	Problem Rating	Possible Variation from Assigned Rating
	2. Moderate	6. ±1 (Low, High)
	3. High	3. -1 (Moderate)
	3. High	1. No Variation

	Groundshaking Intensity Zone Boundary
(7.4/7.0)	Richter Magnitude for Maximum Credible Earthquake/Maximum Probable Earthquake
	Known Fault
	Inferred Fault
	Concealed Fault
?	Location Uncertain
	Direction of Movement
(HA)	Historically Active
(A)	Active
(PA)	Potentially Active
	Inactive
	Axis of Anticline, Direction of Plunge
	Axis of Syncline, Direction of Plunge


WEST HUASNA FAULT
EAST HUASNA FAULT
WHITE ROCK FAULT
SAN ANDREAS FAULT (HA)
MORALES THRUST FAULT
GRAVEYARD FAULT (A)
Switchell
GUADALUPE
SANTA MARIA
State Route 166
Stowell Rd
Betteravia Rd
SUEY FAULT
PEZZONI FAULT
BETTERAVIA
SANTA MARIA FAULT
BRADLEY CANYON FAULT
GAREY
ZONE II
SISQUOC
LIONS HEAD FAULT
ORCUTT
Clark Ave
U S Highway
NACIMIENTO FAULT
LOS PADRES NATIONAL FOREST
LOMPOC
TERRACE FAULTS
LOMPOC
SANTA RITA
HONDA FAULT
PACIFICO FAULT
GAVIOTA
EAGLE FAULT
MORE RANCH
SUMMERLAND
FERNALD POINT FAULT
SANTA BARBARA
CARPINTERIA
VENTURA COUNTY
N
SEISMIC TECTONIC MAP

South Coast Study Area -East
Seismic-Tectonic Map

	Problem Rating	Possible Variation from Assigned Rating
	3. High	3. -1 (Moderate)

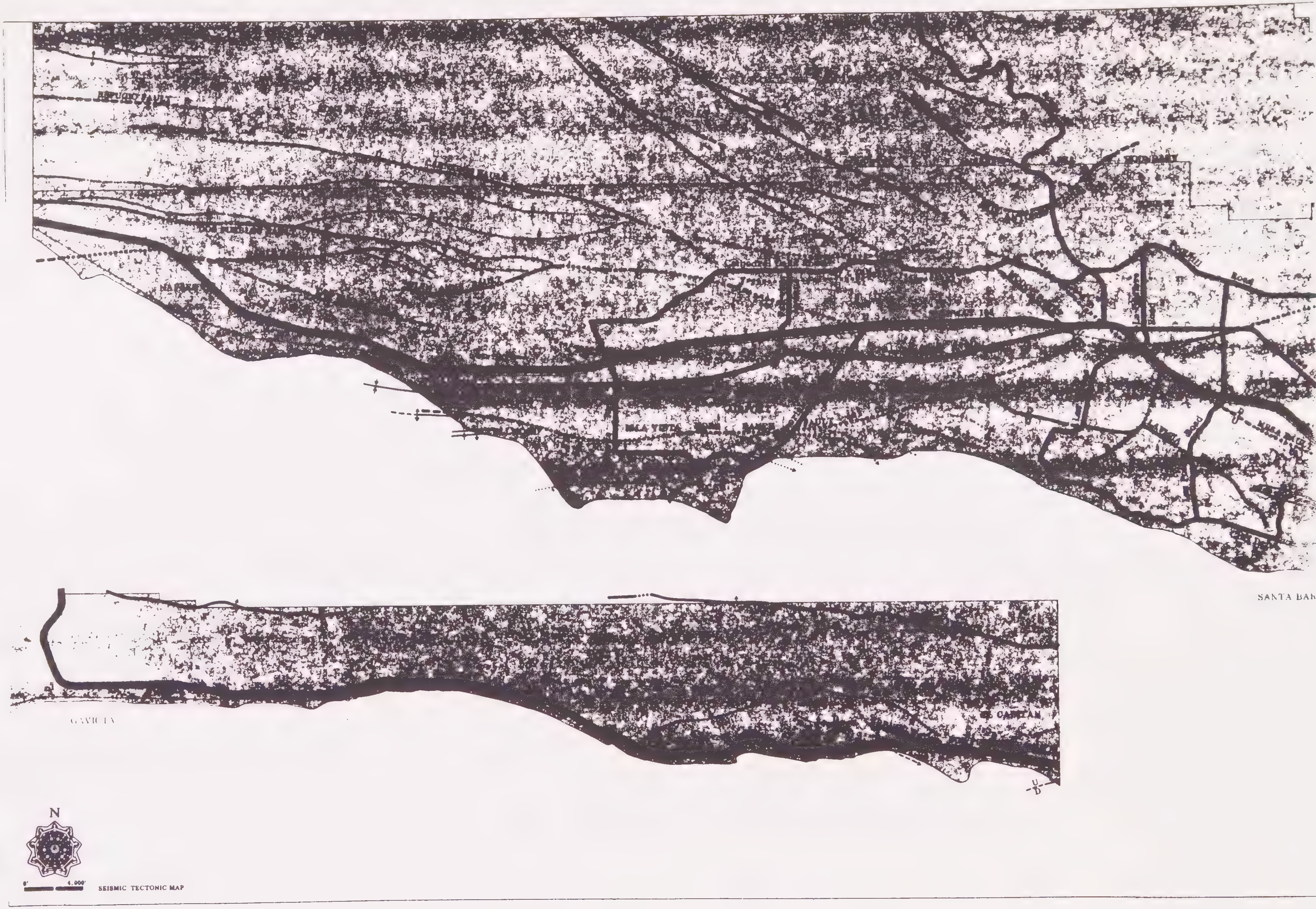
(7.4/7.0)	Richter Magnitude for Maximum Credible Earthquake/Maximum Probable Earthquake
	Known Fault
	Inferred Fault
	Concealed Fault
?	Location Uncertain
(A)	Active
(PA)	Potentially Active
	Inactive
	Axis of Anticline, Direction of Plunge
	Axis of Syncline, Direction of Plunge

SANTA YNEZ FAULT
(7.4/7.0)
(A)
STUDY AREA BOUNDARY
SANTA BARBARA COUNTY
LOS PADRES NATIONAL
MESA FAULT
(A)
SUMMERLAND
SANTA BARBARA
N
0'
4,000'
SEISMIC-TECTONIC MAP

South Coast Study Area ~West
Seismic-Tectonic Map

Problem Rating	Possible Variation from Assigned Rating
3. High	3. -1 (Moderate)

(7.4/7.0)	Richter Magnitude for Maximum Credible Earthquake/Maximum Probable Earthquake
	Known Fault
	Inferred Fault
	Concealed Fault
?	Location Uncertain
(A)	Active
(PA)	Potentially Active
	Inactive
	Axis of Anticline, Direction of Plunge
	Axis of Syncline, Direction of Plunge


SANTA BAR
GAVIOTA
EL CAPITAN
N
0'
4,000'
SEISMIC TECTONIC MAP

Santa Ynez Valley Study Area
Seismic-Tectonic Map

	Problem Rating	Possible Variation from Assigned Rating
	2. Moderate	6. ±1 (Low, High)
	3. High	3. -1 (Moderate)

Groundshaking Intensity Zone Boundary

Known Fault

Inferred Fault

Concealed Fault

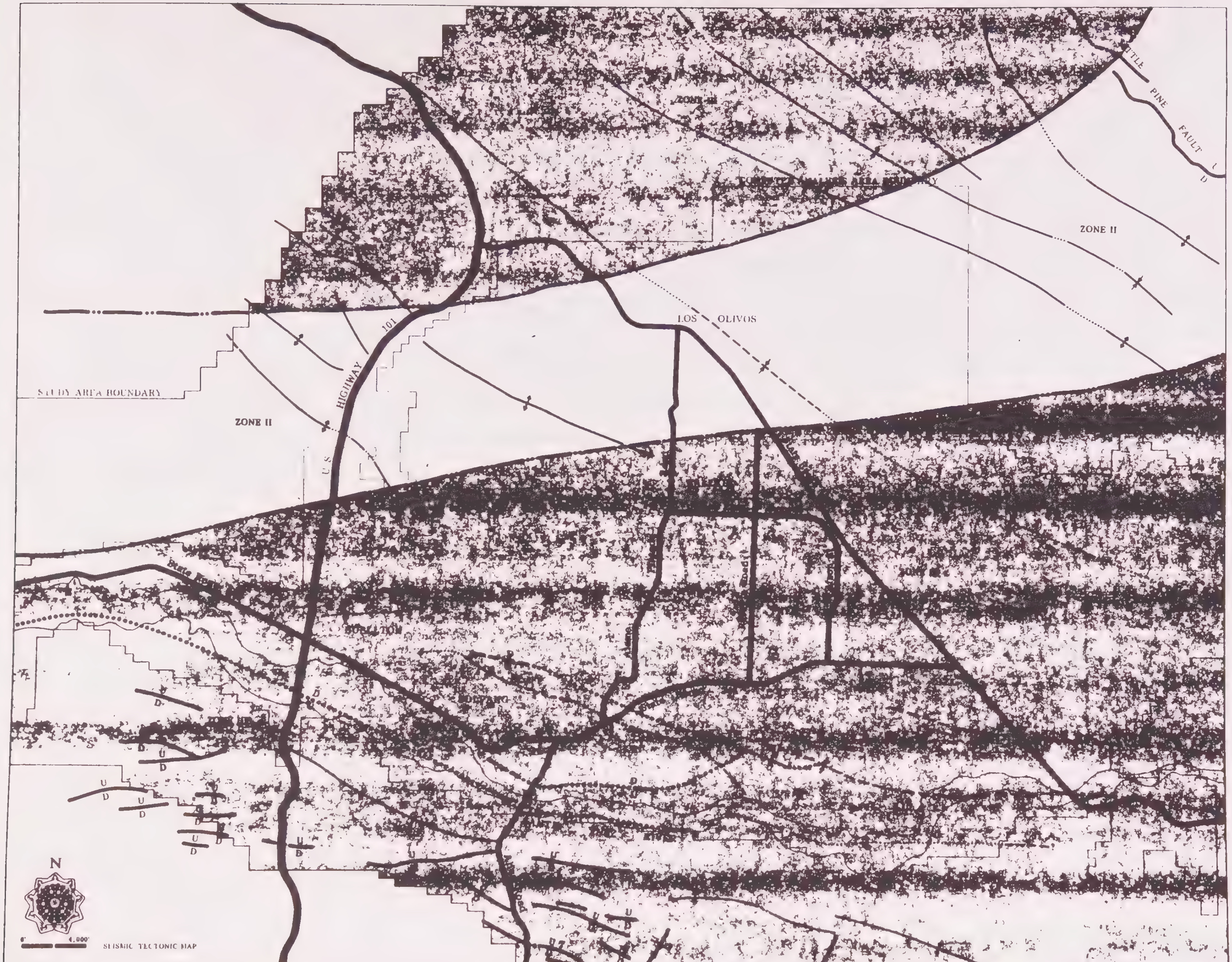
Location Uncertain

(A) Active

Inactive

Axis of Anticline, Direction of Plunge

Axis of Syncline, Direction of Plunge

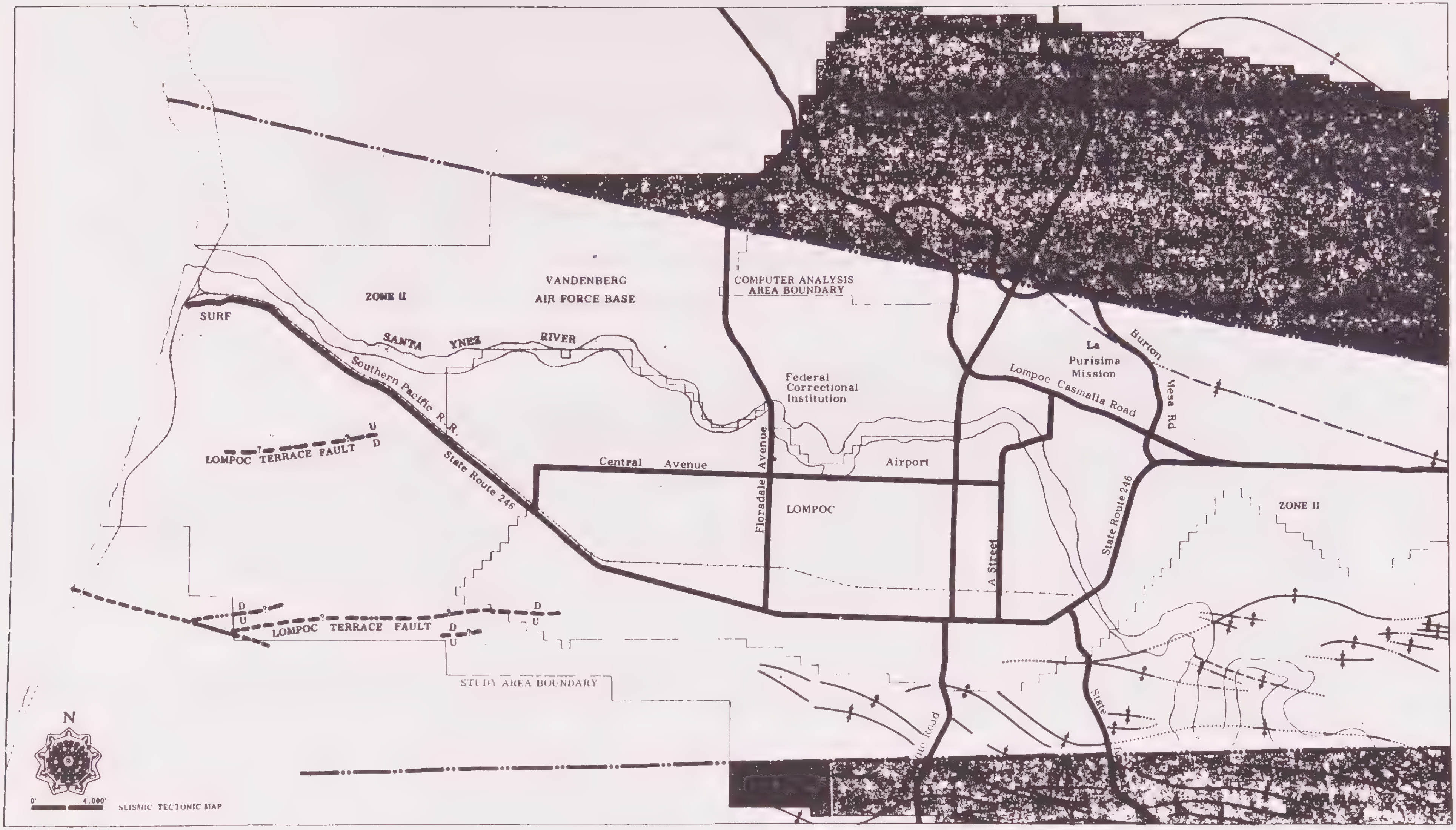


SEISMIC TECTONIC MAP

Lompoc Study Area
Seismic-Tectonic Map

Problem Rating	Possible Variation from Assigned Rating
2. Moderate	6. ±1 (Low, High)
3. High	3. -1 (Moderate)

— • • —	Groundshaking Intensity Zone Boundary
———	Known Fault
– – – –	Inferred Fault
....	Concealed Fault
– – ? – –	Location Uncertain
	Axis of Anticline, Direction of Plunge
	Axis of Syncline, Direction of Plunge



ZONE II
VANDENBERG
AIR FORCE BASE
COMPUTER ANALYSIS
AREA BOUNDARY
SURF
SANTA YNEZ RIVER
Southern Pacific R.R.
State Route 246
La
Purisima
Mission
Burton Mesa Rd
Lompoc Casmalia Road
Federal
Correctional
Institution
LOMPOC TERRACE FAULT
Central Avenue
Airport
Floradale Avenue
LOMPOC
A Street
ZONE II
LOMPOC TERRACE FAULT
STUDY AREA BOUNDARY
N
0'
4,000'
SEISMIC TECTONIC MAP

Santa Maria-Orcutt Study Area
Seismic-Tectonic Map

Problem Rating	Possible Variation from Assigned Rating
2. Moderate	6. ±1 (Low, High)
3. High	3. -1 (Moderate)

Groundshaking Intensity Zone Boundary

Known Fault

Inf[illegible]d Fault

Concealed Fault

(PA) Potentially Active

Inactive

Axis of Anticline, Direction of Plunge

Axis of Syncline, Direction of Plunge

SAN LUIS OBISPO COUNTY
SANTA BARBARA COUNTY
SANTA MARIA RIVER
GUADALUPE
ZONE II
State Route 166
SANTA MARIA
ZONE II
COMPUTER ANALYSIS AREA BOUNDARY
Stowell Road
Santa Maria Valley R R
STUDY AREA BOUNDARY
Black Road
Blosser Road
Betteravia Road
Mahoney Rd
PEZZONI
PEZZONI ANTICLINE
FAULT
SANTA MARIA VALLEY SYNCLINE
BETTERAVIA
SANTA MARIA FAULT
BRADLEY CANYON FAULT
Point Sal Beach State Park
State Route 1
Santa Maria Airport
State Route 135
ZONE II
U.S. HIGHWAY 101
Clark Avenue
VANDENBERG AIR FORCE BASE
ORCUTT
ANTICLINE
MOUNT
CASMALIA
N

Students accepting this as fact have generally supposed that the earthquake originated on some as yet unlocated fault under the Channel; that would agree with the facts, wave or no wave. If there was really no wave, it is a reasonable possibility that this earthquake originated on one of the large inland faults - perhaps even the San Andreas or Big Pine faults, or with more probability, the Santa Ynez fault.

1852, November 26 (probably) - There are slight difficulties about the date; some lists give the year as 1851, others give 1852, October 26. In any case, this was a large earthquake, felt over a wide area which probably included most of Santa Barbara County. The most significant-appearing report states that it opened a series of fissures extending for many miles in Lockwood Valley, which is directly on the course of the Big Pine fault.

1855, July 10 - A locally strong shock in the vicinity of Los Angeles, where a number of buildings were damaged. Bells were thrown down at San Gabriel Mission. An adobe dwelling whose site is now at the Los Angeles County Arboretum (in Arcadia) was wrecked. This earthquake may have originated on the Raymond fault. It was reported as felt as far as Santa Barbara and San Bernardino.

1857, January 9 - The earliest of three known great earthquakes in the California region (the others were in 1872 and 1906). It originated on the San Andreas fault, along which there were displacements, probably extending from the Carrizo Plain in San Luis Obispo County, southeast across the mountains to Burro Flat northeast of Banning.

This is often called the Fort Tejon earthquake, since the buildings at the fort (now a historical monument) were heavily damaged. This was the principal destructive effect, and only one life was lost in the earthquake. However, the nature and geographic extent of the reported faulting and shaking make it reasonably certain that the magnitude was closely comparable with that of the 1906 earthquake (rated at 8.3). The comparatively small loss of life is attributable to the thinly settled character of most of the heavily shaken area at the time.

In Los Angeles, the actual damage reported was less than in the 1855 earthquake, although there was a very strong, slow, swaying motion, and the Los Angeles River was thrown out of its bed. Houses were reported thrown down at San Fernando, and the roof of the Mission church at Ventura was damaged. At Santa Barbara, there is no report of damage to the Mission, but many houses in the town had cracked walls, rocks rolled down the hills, and water was spilled out of the Mission reservoir. There is a report that

the lighthouse at Point Concepcion was severely damaged in this earthquake.

1872, March 26 - The second known great California earthquake, probably greater than those of 1857 and 1906, with its origin in Owens Valley, occurred along a major fault system east of the Sierra Nevada. It was felt with greater or less intensity over almost the whole of California and is listed as "severe" at Santa Barbara, but evidently not damaging there.

1883, September 5 - Shock felt at Los Angeles, Wilmington, Ventura, and Santa Barbara; apparently strongest at Ventura. The earliest of many shocks, usually very imperfectly reported, which appears to have centered offshore, in the region of Santa Barbara Channel and the islands. Definite assignment of epicenters to that area was not possible until the establishment of the seismograph network in Southern California, especially after a station was setup at Santa Barbara in 1927.

1885, April 11 - Moderately strong earthquake felt over a wide area, apparently centering near Las Tablas (north of San Luis Obispo) where there was damage. This earthquake is of general interest because it may have originated on the major Nacimiento Fault, or on one of the active faults close to it in the same region.

1893, June 1 - At Santa Barbara, reported stronger than the preceding quake of May 18. Felt also at Ventura and Nordhoff (now Ojai), but there are no reports from more distant points.

1902, July 27 - Of damaging intensity in the vicinity of Los Alamos. Some damage also at Lompoc. Felt strongly, without damage, at Santa Barbara and San Luis Obispo. Numerous aftershocks were felt in the following days.

1902, July 31 - This was a particularly large aftershock of the preceding; it may even have been larger, but since all available accounts refer to both without much distinction, decision is not possible. In any event, this earthquake was large enough to add greatly to the damage at Los Alamos, where it is stated that not a chimney was left standing, and no house escaped damage. Most of the residents left the area. This is a noteworthy exception to the general rule that aftershocks occurring within a few days are much smaller than the principal shock.

Damaging effects of these two earthquakes are reported as greatest in a strip about 15 miles long and 4 miles wide. This presumably was along the valley in which Los Alamos is located; it may be

accounted for in terms of ground characteristics, but also suggests an active fault. The July 27 and 31 shocks may be related to a succeeding event on January 11, 1915.

1902, December 11 - Three more earthquakes of this group; strongest at Los Alamos, but causing slight damage at Santa Maria, and felt at Lompoc, San Luis Obispo, and Santa Barbara.

1906, April 18 - The third known great California earthquake (magnitude 8.3), was commonly referred to as "the San Francisco earthquake". Heavy losses occurred at San Francisco from the earthquake and particularly from the resulting fire. Damage was also widespread over much of central California. Faulting also occurred along the San Andreas fault from Humboldt County south past San Francisco to the vicinity of San Juan Bautista. The earthquake was felt in most of Southern California, generally as a slow, swaying motion capable of disturbing small bodies of water and swinging suspended objects, but there were no actually damaging effects south of Fresno County.

1915, January 11 - Damage at Los Alamos, especially to chimneys. Field investigation led to placing the epicenter two or three miles east of Los Alamos. It was generally felt throughout Santa Barbara County, and in much of San Luis Obispo and Ventura Counties, and was perceptible as far away as Los Angeles, Bakersfield, and San Jose. There were numerous aftershocks, but none comparable with the initial shock.

1916, October 22 - This shock was felt sharply at Santa Barbara, along the coast southeast as far as Ventura and also on Santa Cruz Island. The epicenter was most probably in the Santa Barbara Channel.

1917, April 12 - This shock was felt sharply at Santa Barbara, along the coast southeast as far as Ventura, and also on Santa Cruz Island. The epicenter was most probably in the Santa Barbara Channel.

1917, April 20 - Another shock, probably also in the Santa Barbara Channel, and somewhat smaller than that on April 12.

1919, January 25 - Shock centering north of Tejon Pass, felt as far as Santa Barbara and Los Angeles, and possibly a foreshock of the next.

1919, February 16 - Shock centering in southwest Kern County with minor damage at Maricopa; concrete floor cracked at Grapevine station, and an oil tank ruptured at Belridge. Felt over a

widespread area, including points as distant as Coalinga and Los Angeles. The geographical extent of the effects, and seismograph recordings at Berkeley, indicate a magnitude somewhat greater than the Tejon Pass shock of October 22, 1916, hence probably over 6. The data do not agree well with origin on the San Andreas fault, but would fit an epicenter on the White Wolf fault near that of the major earthquake of July 21, 1952.

1919, August 26, 4:12 and 6:57 a.m. - Two minor shocks, both felt at Santa Barbara, and both large enough to write seismograph records at Berkeley and Mount Hamilton. The earlier shock was felt over a wider area and wrote larger records than the second. Its epicenter was presumably more distant from Santa Barbara then the second, which was locally stronger there.

1922, March 10 - Magnitude 6.5. Origin on the San Andreas fault in the vicinity of Cholame and Parkfield, where there was damage to brick chimneys, etc., and cracks in the ground. Felt over a large area.

1925, June 29 - The Santa Barbara earthquake. Magnitude 6.3. Heaviest damage at Santa Barbara with loss of life. Felt over a wide area, including practically all of Santa Barbara County.

The nearest seismographs in operations were at Pasadena; data from these and other stations do not permit accurate location of the epicenter. Attempts at such location have usually indicated an offshore origin, but this is not certain. Speculations published at the time of the earthquake suggesting an epicenter well inland from the coast are almost certainly in error.

This earthquake exposed the weakness of the type of construction, especially brick masonry, which had been common in California. It initiated the setting up of new and improved building regulations.

There were many aftershocks, recorded by seismographs and felt in the vicinity of Santa Barbara. (See also entry for June 29, 1926).

1926, February 18 - Felt rather strongly along much of the coast, particularly in Santa Barbara and Ventura Counties. Presumably centered offshore.

1926, June 29 - A strong aftershock of the 1925 earthquake. Some damage at Santa Barbara; one death due to a falling chimney.

1926, September 28 - Another offshore shock, apparently felt more strongly at Ventura than at Santa Barbara.

1927, November 4 - A major earthquake (magnitude 7.3). Centered off Point Arguello. Seismic sea wave (tsunami) rising to 8 feet on the west coast of Santa Barbara and San Luis Obispo Counties. Damage at Lompoc and elsewhere. Sufficient disturbance of the ground along the coastal route of the Southern Pacific Railroad to interrupt service until repairs could be effected. Felt to considerable distances inland. Numerous aftershocks.

1927, November 18 - Damage at Santa Maria. This was an aftershock of the preceding, of considerably lower magnitude, but with epicenter farther north (hence nearer Santa Maria).

1933, March 10 - The Long Beach earthquake, of magnitude 6.3, comparable with the Santa Barbara earthquake of 1925, but with greater total damage and casualities because of its centering in a more densely settled area. Much damage occurred to weak structures, notably school buildings. In consequence, the State Legislature passed the Field Act, which set reasonable standards for earthquake resistant construction in new schools and other public buildings.

The Long Beach earthquake did not reach a damaging level of shaking in Santa Barbara County.

1934, June 7 - Earthquake of magnitude 6 on the San Andreas fault in the vicinity of Parkfield (southern Monterey County). Felt over a wide area. Damage only in and near Parkfield.

1941, June 30 - Magnitude 5.9 - Epicenter offshore near Carpinteria. Damage at Carpinteria and Santa Barbara, especially to buildings damaged in the 1925 earthquake and imperfectly repaired.

1945, April 1 - Epicenter on or near Santa Rosa Island. Magnitude 5.4. Felt at many places along the coast. No reports of damage.

1952, July 21 - Major earthquake (magnitude 7.7) on the White Wolf fault, Kern County. Heavy damage at Arvin and Tehachapi (with loss of life); considerable damage at Bakersfield. Disproportionate damage, in view of distance from the epicenter, at Santa Barbara, seriously affecting structures along State Street, many of which had been damaged in 1925 and 1941.

This earthquake was notable for the strong slow ground oscillations, generally characteristic of major earthquakes effective to considerable distances from the source, touching off landslides and damaging dams. In central Los Angeles and in Long Beach many of the larger business structures had extensive interior damage (especially to plaster, partitions, and loose lighting fixtures)

much like those caused in the same buildings by the Long Beach earthquake of 1933. Old and relatively weak masonry buildings, mostly of one and two stories, were only slightly affected, although such buildings were badly damaged in 1933 (and again in the 1971 San Fernando earthquake).

There were a very large number of aftershocks for many months, some of magnitude 6 or even larger; these were felt by many persons in the Los Angeles and Santa Barbara areas, but were of damaging intensity only in Kern County.

1952, November 21 - Earthquake of magnitude 6 with epicenter near Bryson, in southern Monterey County. There was damage at Bryson and at some other localities in the same area. The earthquake was widely felt. It is of interest as the largest earthquake which can be assigned reliably to the Nacimiento fault system. The level of seismicity to be assumed for the Nacimiento fault and others associated with it is difficult to assign, but the Nacimiento, Huasna, and other faults together constitute a major feature which might reasonably produce a major earthquake.

1957, March 18 - Near Oxnard; magnitude 4.7. Minor damage at Oxnard, Port Hueneme, and Ventura.

1959, September 30 - Off Point Concepcion. Magnitude 4.5. Felt widely in Santa Barbara County. Minor damage only.

1966, June 27 - Magnitude 5.3. Earthquake on the San Andreas fault zone in the Parkfield-Cholame Valley sector, with small fault offsets continuing in the form of gradual creep, with many aftershocks. Comparable with 1922 and 1934 events.

1968, July 4 - Largest of a numerous swarm of shocks originating under Santa Barbara Channel. Magnitude 5.2. Minor damage at Goleta, Santa Barbara and Carpinteria.

1971, February 9 - The San Fernando earthquake. Magnitude 6.4. 64 lives lost, 44 of them in the collapse of two masonry structures dating from the 1920's, at the Veterans' Hospital near Sylmar. No strong effects in Santa Barbara County.

1973, February 21 - Magnitude 5.9. Epicenter a short distance offshore to the southeast of Point Mugu. Damage at Oxnard and vicinity. Possibly originating on Malibu fault system.

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Recurrence Interval

A general discussion on recurrence intervals has been given in the section on Fundamentals of Engineering Seismology. Using the method described, recurrence intervals have been calculated for the San Andreas and Big Pine faults, known active faults on which movement would significantly affect Santa Barbara County.

Recurrence intervals for Richter magnitude 6, 7, and 8 earthquakes have been calculated for the San Andreas fault and magnitude 6 and 7 for the Big Pine fault, as indicated on Table 2. Values of displacement versus magnitude were taken from the least-squares fit curve for historic earthquakes from Bonilla and Buchanan (1970). Housner's idealized relation between length of slipped fault versus magnitude (Figure 9) was used to determine the length of fault rupture (L) applied in equation 2.

Recurrence intervals for magnitude 8 earthquakes were not calculated for the Big Pine fault because this magnitude is in excess of the maximum credible earthquake, previously discussed under Fundamentals of Engineering Seismology.

The values of displacement (D) and rupture length (L) versus magnitude used in the calculations and the calculated recurrence intervals are indicated on Table 2. Because of the uncertainties in the slip rates and data relating magnitude to displacement and rupture length, the calculated recurrence intervals may be in error by a factor of two. The sources of data for the long-term slip rates are given under the detailed descriptions of the San Andreas and Big Pine faults.

In general, the greater the displacement of geologic units the greater the number of earthquakes that have occurred. Although data are insufficient to estimate recurrence intervals for other faults in Santa Barbara County, total displacements are included below; these data provide a qualitative basis for comparing the earthquake risk of individual faults.

CALCULATION OF EARTHQUAKE RECURRENCE INTERVALS
SAN ANDREAS AND BIG PINE FAULTS

Data on fault displacement and rupture length:	Earthquake Magnitude 6	7	8
Fault Displacement (D), cm. from Bonilla and Buchanan (1970)	27	120	520
Fault Rupture Length (L), km. from Housner (Figure 9)	8.1	42	320

Earthquake Recurrence Intervals (years):

San Andreas Fault (southern segment)
Length (L_t) = 500 km; slip rate (S) = 3 cm/year

	6	7	8
At a point on the fault (R_x)	10	40	200
Over length of fault (R_t)	0.2	3	100

Big Pine Fault
Length (L_t) = 95 km; slip rate (S) = 0.3 cm/year

	6	7	8
At a point on the fault (R_x)	90	400	*
Over length of fault (R_t)	8	200	*

* Magnitude 8 earthquake not calculated. Considered in excess of maximum credible earthquake

TABLE 2

Description of Individual Faults

The fault names have been taken from the following 1:250,000 scale sheets of the California geologic map: San Luis Obispo (Jennings, 1958); Santa Maria (Jennings, 1959); Los Angeles (Jennings and Strand, 1969); Bakersfield (Smith, 1964), with some modifications and additions from the 1:750,000 scale preliminary California Fault and Geologic map (Jennings, 1973).

There is a natural tendency to investigate and name faults in more accessible, populated areas rather than in remote wilderness locations. Thus, more faults have been named and described in the immediate area of the Goleta - City of Santa Barbara - Carpinteria coastal area than in the back-country of the Santa Ynez and San Rafael Mountains. This bias may be desirable because it tends to place emphasis on the areas of greatest concern with respect to earthquake hazard.

The individual faults are described in detail in the following paragraphs in alphabetical order under each category of relative fault activity beginning with historically active. The faults are further identified and summarized with respect to activity, length, magnitude and age in Table 3.

The geologic age as determined by fossils is given for the rock units displaced by the faults. Table 4 shows the relationship between the geologic age and the approximate absolute age in years from radiometric measurements.

Historically Active - The following faults are considered historically active (movement in historic time) as defined in the previous section Fundamentals of Engineering Seismology.

B i g P i n e F a u l t - The east-west to northeast trending Big Pine fault forms the approximate boundary between northwest striking faults and physiographic trend of the Coast Ranges to the north and east-west structures of the Transverse Ranges to the south. The Big Pine fault has been traced 53 miles to the southwest from its intersection with the San Andreas fault; it is a reverse fault with left lateral slip. According to Jennings and Strand (1969), in central Santa Barbara County, the west end of the Big Pine fault curves to the northwest and intersects the northwest trending Camuesa fault.

Jennings (1972) indicates that the eastern 43 miles of the Big Pine fault has had displacement during historic time. The displacement is believed to have occurred in 1852. Townley and Allen (1939) report that during 27-30 November 1852, continued shocks disturbed an area of over 900 square miles from San Luis Obispo to San Diego and east to the Colorado River. A zone of fissures at

CLASSIFICATION OF FAULT ACTIVITY
SANTA BARBARA COUNTY

Fault Identification	Fault Length (miles)	Estimated Magnitude of Maximum Credible Earthquake[1] & [2]	Age of Youngest Rock Unit Displaced
Historically Active (HA):			
Big Pine	53	7.1	0 - 11,000 years
San Andreas	620	8.4	0 - 11,000
Active (A):			
Big Pine Extension	70	7.2	Fault not verified
Graveyard - Turkey Trap	7	5.6	0 - 11,000
Mesa	4+	5.0+	0 - 11,000
More Ranch	9+	5.8+	0 - 11,000
Nacimiento	170	7.6	0 - 11,000[3]
Pacifico	13+	6.3+	0 - 11,000[4]
Santa Cruz Island	13+	6.3+	0 - 11,000
Santa Rosa Island	12+	6.2+	0 - 11,000
Santa Ynez	75+	7.2+	0 - 11,000[4]
Potentially Active (PA):			
Arroyo Parida	24+	6.6+	11,000-500,000
Bradley Canyon	5	5.2	11,000-500,000[5]
Carpenteria	3+	4.5+	11,000-500,000
Goleta	3	4.5	11,000-500,000
Mission Ridge	5+	5.2+	11,000-500,000
Red Mountain	13+	6.3+	11,000-500,000[6]
Rincon Creek	15+	6.4+	11,000-500,000
San Jose	9	5.8	11,000-500,000
Inactive:			
Carneros	6½	(5.5)[2]	500,000 - 4 Million[7]
Camuesa	23	(6.1)	12 - 16 Million
Dos Pueblos	4½	(5.1)	16 - 22 Million
Eagle	5	(5.2)	10 - 16 Million
East Huasna	50	(7.0)	10 - 12 Million
Erburu	1+	(3.5+)	12 - 16 Million
Glen Anne	3½	(4.8)	500,000 - 4 Million
Hildreth	13	(6.2)	12 - 16 Million
Honda	7	(5.6)	10 - 16 Million
Las Varas	3	(4.5)	16 - 22 Million
Lavigia	4½+	(5.1+)	500,000 - 4 Million
Lion's Head	5+	(5.2+)	4 - 12 Million[8]
Little Pine - Loma Alta	36	(6.8)	500,000 - 4 Million[9]
Lompoc Terrace	5½+	(5.3+)	500,000 - 4 Million
Modoc	1½	(3.8)	500,000 - 4 Million
Montecito	5	(5.2)	500,000 - 4 Million[10]
Morales	35	(6.8)	1½ - 4 Million[9]
Munson Creek	25	(6.7)	16 - 22 Million[11]
Ozena	25	(6.7)	12 - 16 Million
Pezzoni	4+	(3.8+)	4 - 12 Million
Refugio	6	(5.4)	16 - 22 Million
San Antonio	2	(4.2)	16 - 22 Million
San Pedro	4	(5.0)	16 - 22 Million
Santa Maria	7	(5.6)	500,000 - 4 Million
South Cuyama	37	(6.9)	1½ - 4 Million[9]
Suey	18+	(6.5+)	10 - 12 Million
Whiterock	17	(6.4)	1½ - 4 Million
Ygnacio	1½	(3.8)	16 - 22 Million

TABLE 3

NOTES

1 Based on Housner's relationship between fault rupture length and Richter magnitude assuming the maximum credible earthquake results from ruptures along 50% of the fault length.

2 Magnitudes for inactive (in parentheses) indicate the potential size earthquake the fault might generate if it were active. There is a very large scatter in the data used to compute the maximum credible earthquake, particularly below magnitude 6.5. Consequently, the values shown are not accurate to the degree indicated by the decimal. There is approximately a 70% probability that the maximum credible earthquake will be within $\pm$ 0.5 magnitude of the values shown.

3 Evidence of Recent (0 - 11,000 years) movement is found along a segment of the fault 25 miles north of Santa Barbara County. Portions of the fault within Santa Barbara County are considered potentially active or inactive.

4 A historic (1927) earthquake occurred along the possible subsea extension of the Pacifico branch of the Santa Ynez fault. On this basis, these faults are considered "possibly historically active".

5 Sediments within groundwater basin have been displaced but there is no evidence of displacement of bedrock adjacent to basin. Considered a minor fault, not likely to generate a destructive earthquake.

6 Elevation changes along re-surveyed level line across fault and historic (1941) earthquake on possible subsea extension of fault suggest movement within past 0 - 11,000 years. On this basis, the fault could be classified as "possibly historically active".

7 Investigation by G. A. Brown and Associates for Goleta Water District noted "Glen Anne fault had affected the Terrace Deposits"; could be considered "possibly potentially active".

8 Possible elevation change along re-surveyed level line across fault could suggest recent movement (historically active); however, Terrace Deposits (11,000 to 500,000 years old) apparently are not displaced.

9 Situated at physiographic boundary between mountainous area and lowlands; topographic evidence of recent displacement would be quickly obliterated because of rapid erosion and deposition at such a location.

10 Montecito fault could be considered "possibly active" or "possibly potentially active" based on Hydrogeologic Investigation by Geo Technical Consultants which indicates "offsets in Terrace Deposits and alluvium west of Montecito".

11 On the basis of alignment of Munson Creek fault with Big Pine and Santa Ynez faults, Fisher and Dibblee (1961) suggest these faults are all situated over an active shear zone in basement rock beneath a thick sedimentary cover. There is no other evidence to suggest that the Munson Creek fault is active.

TABLE 3
(continued)

GEOLOGIC/ABSOLUTE AGE

	Geologic Age	Absolute Ages (Approximate Years before present)	Typical Rock Type or Geologic Feature
Quaternary	Holocene (Recent)	0 - 11,000	Recent alluvium (sand and gravel in recent river valleys and stream channels); topographic evidence of displacement such as recent scarps, sag ponds, drainage offsets; historic earthquakes; ground rupture during earthquake and creep; elevation changes along surveyed lines
Quaternary	Late Pleistocene	11,000 - 500,000	Old alluvium, terrace deposits (uplifted and dissected alluvium) and fanglomerate (alluvial fan deposits)
Quaternary	Early Pleistocene	500,000 - 1½ million	Poorly consolidated sedimentary rocks filling lowland basins, water bearing
Tertiary	Late Pliocene	1½ - 4 million	Poorly consolidated sedimentary rocks, commonly water bearing
Tertiary	Early Pliocene	4 - 10 million	Consolidated sedimentary rocks
Tertiary	Upper Miocene	10 - 12 million	Consolidated sedimentary rocks
Tertiary	Middle Miocene	12 - 16 million	Consolidated sedimentary and volcanic rocks
Tertiary	Lower Miocene	16 - 22 million	Consolidated sedimentary rocks
Tertiary	Oligocene	22 - 38 million	Consolidated sedimentary rocks
Tertiary	Eocene	38 - 53 million	Consolidated sedimentary rocks
Tertiary	Paleocene	53 - 65 million	Consolidated sedimentary rocks
Tertiary	Cretaceous	65 - 135 million	Consolidated sedimentary rocks

Relation between geologic age and absolute age in years from radiometric measurements. Modified from Ziony (1973) and Dibblee (1973).

TABLE 4

least thirty miles long was opened in Lockwood Valley located near the east end of the Big Pine fault. A rupture length of 30 miles long suggests an earthquake with a magnitude of about 7 (Figure 9). Horizontal stream offsets of up to 3000 feet occur along the central and eastern portion of the Big Pine fault (Hill and Dibblee, 1953), and Larsen (1958) noted displacement of a late Pleistocene alluvial fan of up to one mile. Evidence of Quaternary and historic movement has been recently noted on the ten-mile long, western-most segment of the Big Pine fault, according to Comstock (in preparation).

Hill and Dibblee (1953) suggest 8 miles (13 km), Crowell (1962) 5 to 10 miles (8 to 16 km), and Carman (1964) 4 miles (6 km) of horizontal displacement on the Big Pine fault over the past 10 million years since Miocene. These values of displacement over 10 million years yield slip rates (S) ranging from .06 to .16 cm/year. Kahle (1966) has suggested 4 miles (6 km) of horizontal movement since late Pliocene. Assuming that the displaced late Pliocene rocks are approximately 2 million years old (Heirtzler et al., 1968; Dibblee, 1973), an average slip rate of .3 cm/year is determined. Comparing this with an average slip rate of 3 cm/year for the San Andreas fault, the earthquake generating potential of the Big Pine fault is estimated to be one-tenth as great as the San Andreas fault. Recurrence intervals for 6 and 7 Richter magnitude earthquakes required to relieve elastic strain accumulation along the Big Pine fault for a slip rate of .3 cm/year have been calculated and are listed on Table 2.

As previously noted, the west end of the Big Pine fault curves to the northwest and intersects the northwest trending Camuesa fault north of Lake Cachuma. However, an east-west trending lineation has been noted on satellite imagery (NASA Earth Resources Technology Satellite, ERTS-1) which could be a western continuation of the Big Pine fault (Estes, 1973; Comstock, in prep.). This lineation extends 43 miles westward from the mapped terminus of the fault, through the town of Los Alamos and to the coast through San Antonio Creek. A University of California at Santa Barbara graduate student, Steve Comstock, is presently involved in study of this feature as well as the western area of the mapped Big Pine fault. Comstock's preliminary investigations on the western continuation of the fault included study of 1:120,000 and 1:60,000 color infrared aerial photographs of the area of the ERTS-1 lineament, and subsequent field study of the ground locations. East-west trending lineaments were observed and substantiated by ground check in the area between the Camuesa fault and west of Los Alamos.

Between 1934 and 1966, three earthquake epicenters greater than magnitude 4, and five epicenters of 3 to 4 magnitude occurred along this ERTS-1 lineament (Hamilton, et al., 1969). Several damaging earthquakes occurred along the lineation near Los Alamos during 1902 and 1915 (Townley and Allen, 1939); at least three of these earthquakes are estimated to be of magnitude 6 or greater (Lamar et al., 1973, pocket map). Additionally, there is a pronounced difference in surface and subsurface geologic structural trends north and south of this possible western continuation of the Big Pine fault. Structures north of the lineament have an average trend of north-northwest, whereas the median structural grain south of this line trends approximately 40° more westerly (Comstock, in preparation). This contrast reflects the same Coast Ranges-Transverse Ranges boundary marked by the Big Pine fault to the east.

During a recent landslide investigation by Moore & Taber on Vandenberg Road south of San Antonio Creek, a review of 1938 aerial photographs disclosed offsets of three small stream gullies. The gullies are offset in a left lateral sense, and when aligned with a straight portion of the valley wall show a trend of about N60W. The alignment of these jogs in the local drainage pattern could be fortuitous or could represent ground displacement along a small fault during historic times (1902 or 1915) associated with movement along the westerly extension of the Big Pine fault. The jogs are more subdued in 1960 photographs

Thus, seismic and structural evidence support a western continuation of the Big Pine fault to the Pacific Coast. However, Willot (1972) shows no significant elevation change across the possible western continuation of the Big Pine fault near the coast along San Antonio Creek during a thirteen year period, 1958-1971.

S a n A n d r e a s F a u l t - The San Andreas, the principal active fault in California, extends for over 600 miles (1000 km) from at least the Salton Sea area northwestward to the Pacific Ocean near Point Arena. Although at its closest point the trace of the San Andreas fault is located 7 miles from the sparsely populated northeast corner of Santa Barbara County, a major earthquake on the southern segment of the San Andreas fault would subject the County (especially the Cuyama Valley) to severe ground accelerations. Two of the three largest (Richter magnitude 8 or greater) historic earthquakes in California have occurred along the San Andreas fault; these were the 1906 San Francisco earthquake and the less well known 1857 Fort Tejon earthquake. Although the trace of the 1857 break is not completely known, available evidence suggests that the surface rupture extended opposite Santa Barbara County from near San Bernardino, northwest at least 220 miles (350 km) to Cholame, approximately midway between Los

Angeles and San Francisco (Allen, 1968). According to Olsen (1972), virtually every house in Santa Barbara was damaged by the 1857 Fort Tejon earthquake. Thompson and West (1883) state that many houses in Santa Barbara were damaged by cracks in adobe walls, rocks rolled down hills, and water spilled out of the Mission reservoir; there is no reference to damage at the Mission or in the official Mission histories. According to Charles Richter (personal communication, 1974), all authorities report that the 1857 earthquake caused collapse of the tile roof at San Buenaventura Mission church.

Wallace (1968) has suggested that many of the 30-foot offsets of stream channels along this segment of the San Andreas fault may have formed during the 1857 earthquake. By comparison, the maximum horizontal displacement during the magnitude 8.3 1906 San Francisco earthquake was 21 feet. Therefore, the horizontal displacement suggests that the Richter magnitude of the 1857 earthquake was at least as great as the 1906 San Francisco earthquake, or magnitude 8.3+.

The portion of the San Andreas fault which broke during the 1857 earthquake has been extremely quiet seismically (Brune and Allen, 1967), and there is no evidence of creep (Brown and Wallace, 1968). Allen (1968) has suggested that this segment of the San Andreas fault is locked because of the curvature as it passes through the Transverse Ranges, and that strain release along the San Andreas fault in this area occurs principally as a result of major earthquakes similar to the 1857 event.

The San Andreas fault has been extensively studied, and considerable data on the offset of geologic units along the fault are available. Hill and Dibblee (1953) were the first to propose the concept of cumulative horizontal slip of hundreds of miles on the San Andreas fault as a result of incremental fault displacement during earthquakes. In a more recent analysis, Huffman (1972) presented data which indicate that the average slip rate for the past 10 million years has been about 3 cm/year in the central Coast Ranges. This is consistent with geodetic data indicating current relative motion of $3.2 \pm .5$ cm/year in the same area (Savage and Burford, 1973).

For a slip rate of 3 cm/year and a maximum displacement of about 30 feet (900 cm) during the 1857 Fort Tejon earthquake, a recurrence interval of 300 years is indicated. Wallace (1970) has estimated that recurrence intervals calculated for the San Andreas are probably incorrect by at least a factor of 2; thus, the recurrence interval may be between about 150 and 600 years.

It should also be emphasized that the historic record is not adequate to verify Allen's (1968) theory that only major and infrequent earthquakes occur along the San Andreas fault segment opposite Santa Barbara County. Sufficient elastic strain has probably accumulated for at least a magnitude 7 earthquake, which could subject Santa Barbara County to severe earthquake accelerations.

Recurrence intervals for the release of elastic strain by Richter magnitude 6, 7, and 8 earthquakes for a slip rate (S) of 3 cm/year along the San Andreas fault are listed on Table 2.

Active (A) - The following faults are considered active (movement in last 11,000 years) as defined in the previous section, Fundamentals of Engineering Seismology.

Big Pine Extension - Described previously under Big Pine fault.

Graveyard-Turkey Trap - Upson and Worts (1951) indicate two 4 mile long en echelon faults which underlie the Holocene alluvium of central Cuyama Valley. The existence of these faults is based on the nearly east-west alignment of springs and the Graveyard and Turkey Trap group of ridges. The ridges are 200-400 feet wide and rise to 35 feet above the alluvial plain. Based on the data presented by Upson and Worts (1951), these features could be folds rather than faults in the alluvium. They may be secondary features caused by movement on a fault which cuts bedrock beneath the alluvium. Based on the locations of the en echelon ridges the total length of such a fault zone is estimated to be 7 miles.

Mesa Fault - The topographically high mesa in the southwest part of Santa Barbara is believed to be uplifted along the Mesa fault. As indicated by Dibblee (1966), the Mesa fault trends from its interesection with the More Ranch - Mission Ridge fault 4 miles southeast to the ocean. The Mesa fault may continue onshore to the east as the Carpinteria or Rincon Creek fault. Cross sections prepared by Dibblee (1966) indicate 600 feet vertical displacement of Pleistocene fanglomerate and 2500 feet vertical displacement of late Pliocene to Pleistocene sediments.

The northeast facing cliff of the mesa is considered to represent the fault scarp eroded southward from the fault trace by Mission Creek (Olsen, 1972). The fault is covered by alluvium, but the location mapped by Dibblee (1966) has been essentially verified along the southeast segment of the fault by gravity profiles over the fault (Olsen 1972). The trace of the fault is less well defined along the westerly part and gravity profiles are more subdued and flattened out. The trace in the southeastern part

of Santa Barbara is defined by historic hot springs, an anomalous "mound" and a possible scarp (Olsen, 1972). Many features suggest tectonic creep; however, en echelon cracks in roadways, "push outs" in sidewalks and steps, and disrupted concrete parking areas are not necessarily continuous. Proof of tectonic creep, however, requires more observations (Olsen, 1972): but there appears to be sufficient evidence to arouse suspicion that the fault is active and worthy of additional study.

According to Willott (1972), 2.1 cm of vertical movement occurred across the fault along a level line surveyed in 1959 and 1970, and Jennings (1972) indicates Quaternary displacement along the Mesa fault.

A series of precise level lines have been established across the fault by A. G. Sylvester and students at University California at Santa Barbara (UCSB). Data regarding these lines as well as other instrumental measurement points are noted in Table 5 and the instrument locations are shown in Figure 19.

In 1925, a magnitude 6.3 earthquake occurred beneath the ocean about 10 miles south-southwest of Santa Barbara (Calif. Dept. Water Res., 1964). Willis (1925) suggested that the earthquake occurred on the Mesa fault; this would require a shallow dip on the Mesa fault. Hill (1932) questioned Willis' hypothesis because of the relatively steep surface dip of the fault. Jennings' (1972) map suggests that movement on the offshore continuation of the Oak Ridge fault of Ventura County is more likely to have caused this earthquake. According to Charles Richter (personal communication, 1974), because of the inadequate seismograph records, the epicenter may easily be in error by 10 miles; he prefers an origin on the More Ranch fault and perhaps the Mission Ridge fault.

More Ranch - The More Ranch fault trends east-west for 9 miles near the coast south of Goleta; the eastern end curves and may continue east as the Mission Ridge fault (Dibblee, 1966). The western portion of the More Ranch fault was originally named the Elwood fault by Hill (1932). The late Pliocene to Pleistocene sediments north of the fault have been downdropped up to 2000 feet at the east end; displacement decreases to the west and dies out near the ocean. Dibblee's (1966) map indicates displacement of Recent alluvium as well as old alluvium. Geologically recent movement is suggested by the north facing scarp which bounds the north edge of the coastal mesa at the east end and a small north facing scarp near the coast at the west end of the fault (Dibblee, 1966).

INSTRUMENTAL MEASUREMENT OF CRUSTAL MOVEMENT
Santa Barbara County
University California at Santa Barbara

Fault	Measurement Type & Number	Locality and Site	Date Installation or Observation*
Santa Ynez (North branch)	Q27	Santa Ynez Mountains: Alisal Ranch	1971*
Santa Ynez	Q30	Jameson Lake: Juncal	1970, 1971*
Santa Ynez	Q31	Wheeler Springs: Wheeler Gorge	1971
More Ranch	Q32	Santa Barbara: Mescalitan	1970
Channel Faults	NL17	Santa Barbara Channel	1971 (5 yr. intervals)
Santa Ynez	L7	Santa Ynez: Baseline	1970
Santa Ynez	L8	Santa Barbara: Jameson Lake	1970
Mesa	L9	Goleta: Golf Course	1970
Mesa	L10	Santa Barbara: Crosstown	1970
Mesa	L10	Santa Barbara: Lorinda	1970
Mesa	L10	Santa Barbara: Cook	1970
Mesa	L11	Santa Barbara: Burton Mound	1970
Santa Cruz Island	C54	Santa Cruz Island: Stanton Ranch	1969

Q = Small Triangulation Net
NL = Trilateration Network
L = Level Line
C = Creepmeter

Date Source: Greensfelder, R.W., 1972, "Crustal Movement Investigation", Special Publication 37, California Division of Mines & Geology

TABLE 5

FIGURE 19

LOCATION OF CRUSTAL MOVEMENT INSTRUMENTS AND LEVEL LINES, SANTA BARBARA COUNTY (from Greensfelder, 1972)

N a c i m i e n t o - The Nacimiento fault trends from its intersection with the Big Pine fault in Santa Barbara County 170 miles northwest to the Pacific Ocean near Point Sur. It is considered to be a strike-slip fault with a right lateral sense of movement. This structural zone is considered to mark an important boundary between different types of ancient basement rocks within the Coast Ranges (Page, 1966). However, most of the displacement occurred in pre-late Miocene time or more than 10 million years ago, and only a few hundred feet of post-late Miocene displacement has occurred (Vedder and Brown, 1968).

According to Hart (comment in Vedder and Brown, 1968), the Rinconada fault which branches from the Nacimiento fault 25 miles north of Santa Barbara County shows evidence of geologically recent movement. Hart has noted sagponds, small scarps, and offset drainage along the Rinconada fault. The Nacimiento fault shows similar features near its intersection with the Rinconada fault. Richter (1969) has suggested that a magnitude 6 earthquake located near Bryson in 1952 may have occurred on the Nacimiento fault at depth. Bryson is located approximately 70 miles north of Santa Barbara County. Jennings (1972) indicates that a 10 mile long segment of the Nacimiento fault in northern-most Santa Barbara County has Quaternary displacement, but the 32 mile long segment which extends southeast to its junction with the Big Pine fault has no recognized Quaternary movement.

P a c i f i c o - The Pacifico fault trends east-west 13 miles at the western end of the Santa Ynez Mountains and meets the ocean near the mouth of Jalama Creek (Roubanis, 1963). Dibblee (1950) considers the Pacifico fault to be a member of the Santa Ynez fault zone because of its similar trend and location directly west of the intersection of the north and south branches of the Santa Ynez fault. The north branch of the Santa Ynez fault intersects the Pacifico fault 10 miles from the ocean.

According to Dibblee (1950), the maximum vertical displacement of the Pacifico fault amounts to 5000 feet, and drag folds indicate a large component of horizontal movement. Roubanis (1963) believes that displacement is predominately horizontal and is approximately 2 miles. Sagponds have been reported along the Pacifico fault (Roubanis, 1963), and vertical movement across the fault is indicated on the profile showing elevation changes between 1957-60 and 1971 prepared by Willott (1972). Jennings (1972) indicates Quaternary movement along the Pacifico fault west of its intersection with the north branch of the Santa Ynez fault.

S a n t a C r u z I s l a n d - The Santa Cruz Island fault trends west-northwest for 13 miles across the center of Santa Cruz Island. Erosion along this zone has formed the prominent Central

Valley. According to Rand (1931), the rocks on opposite sides of the fault are very dissimilar so that the amount of displacement is not determinable. Bremmer (1932) indicates that the minimum displacement of middle Miocene volcanic rocks amounts to 4000 feet, and Weaver (1969) indicates that the vertical displacement is 7500 feet. Based on the offset of unique middle Miocene volcanic rocks, Weaver (1969) estimates one mile of horizontal displacement.

Geologically recent movement is indicated by displacement of Pleistocene terrace deposits (Rand, 1931) and horizontal offset of stream courses (Rand, 1931; Weaver, 1969). Jennings (1972) indicates recognized Quaternary movement over the length of the Santa Cruz Island fault.

S a n t a R o s a I s l a n d - The Santa Rosa Island fault trends east-west across central Santa Rosa Island. Based on a comparison of middle Miocene volcanic rocks, Weaver (1969) suggests a maximum of 10 miles of horizontal displacement on the Santa Rosa fault. Horizontal offset of stream courses of up to one mile and a possible 325 feet displacement of Pleistocene terrace deposits (Kew, 1927), suggests geologically recent movement. Jennings (1972) indicates that Quaternary displacement has occurred over the length of the Santa Rosa Island fault.

S a n t a Y n e z - The Santa Ynez fault trends east-west 75 miles from its intersection with the Agua Blanca thrust fault in eastern Ventura County to Gaviota Pass in western Santa Barbara County. At Gaviota Pass the Santa Ynez fault splits into a south branch which interesects the coast 7 miles to the southwest, and a north branch which continues 7 miles further west. The fault system is characterized as a high angle, oblique slip fault with considerable left lateral slip. Along most of its course the Santa Ynez fault marks the base of the steep north-facing escarpment of the Santa Ynez Range; the south block of the fault has been uplifted to form the mountain range. The maximum vertical separation at the base of Eocene sediments indicated on structure sections (Dibblee, 1950, 1966) is 9500 feet. Dibblee (1966) has noted that the Tertiary sedimentary rocks on opposite sides of the Santa Ynez fault are vastly different. He believes that the differences may be explained by several miles of horizontal displacement, the north block having moved west.

Some investigations have supported Dibblee's hypothesis of such major horizontal displacement. Edwards (1971) suggests 37 miles of horizontal movement of lower Miocene sediments along the Santa Ynez fault, and McCracken (1969) believes that Oligocene sediments are horizontally displaced 12 miles. On the basis of a detailed study of Eocene sediments, Schroeter (1972) has suggested 9 miles (15 km) of horizontal displacement. In contrast Schmitka (1973)

believes that Eocene rocks have been horizontally displaced 30 miles; however, he indicates that the north block of the fault has moved east. This is opposite to the movement direction suggested by Dibblee (1966) and the other investigations summarized above.

Other geologists question whether significant horizontal displacement in either direction has occurred along the Santa Ynez fault. Link (1971) believes that a maximum of only 1-2 miles of post Eocene horizontal displacement has occurred, and O'Brien (1973) suggests that the distribution of rock types in Oligocene sediments precludes significant horizontal movement across the south branch of the Santa Ynez fault. Opinions on the magnitude and direction of horizontal movement on the Santa Ynez fault are too contradictory to determine earthquake recurrence intervals from the long-term horizontal slip rate as has been accomplished for the Big Pine and San Andreas faults.

Recent horizontal movement is indicated by displacement of stream courses of a few hundred feet to 3 miles (Dibblee, 1966) and possible offset of Pleistocene terrace deposits (Page et al., 1951). According to Arthur G. Sylvester (personal communication in Sage, 1972), scarps and sagponds occur along the Santa Ynez fault north of Carpinteria. Jennings (1972) indicates that Quaternary displacement has occurred over the entire length of the Santa Ynez fault.

A magnitude 7.5 earthquake occurred off of Point Arguello in 1927; Hamilton et al. (1969) has suggested that the earthquake occurred on a western extension of the Santa Ynez fault. This epicenter is aligned with the Pacifico fault (Calif. Dept. Water Res., 1964), which is a member of the Santa Ynez fault zone. Willott (1972) has compared elevations determined in 1957 and 1971 along a traverse across the south branch of the Santa Ynez fault and reports 0.8 cm displacement.

Potentially Active (PA) - The following faults are considered potentially active (movement between 11,000 - 500,000 years) as defined in the previous section Fundamentals of Engineering Seismology.

A r r o y o P a r i d a - The Arroyo Parida fault trends east-west along the south slope of the Santa Ynez Mountains from near Toro Canyon for 7 miles to the eastern boundary of Santa Barbara County. The presumed continuation of the Arroyo Parida fault further east has been named the Santa Ana fault. The east end of the Santa Ana fault is overridden by the San Cayetano thrust fault 17 miles east of Santa Barbara County. The west end of the Arroyo Parida fault is aligned with the Mission Ridge fault; the 6 mile gap in between is obscured by alluvium and Pleistocene fanglomer-

ate. According to Lian (1952), a branch of the Arroyo Parida fault at its west end trends southwest down Picay Creek and meets the coast west of Ortega Hill. The existence of this branch fault is based on truncated rock units and a turn in the scarp eroded along the fault (Lian, 1952). Willis (1925), Bailey (1954) and Muir (1968) also show a south branch of the fault at its west end.

The maximum vertical displacement along the Arroyo Parida fault noted by Chauvel (1958) amounts to 2700 feet (the north side down). Chauvel (1958) suggests a major component of horizontal displacement on the basis of striae in the fault plane and offset structural highs. Lian (1952) found no evidence for horizontal movement and estimates 2000-4000 feet of vertical displacement of Oligocne sediments.

Stream deflections along the fault may be the result of erosion along the fault zone rather than geologically recent horizontal displacement (Lian, 1952); not all streams show offsets (Chauvel, 1958). Cross sections prepared by Muir (1968) indicate displacement of late Pleistocene water bearing sediments and Pleistocene alluvium. Pleistocene fanglomerate exposed on a hill between Toro Canyon Creek and Garrapata Creek (Dibblee, 1966) appears to be uplifted along the south side of the fault. Pleistocene fanglomerate has also been displaced along the Mission Creek fault, which is aligned with the west end of the Arroyo Parida fault. Jennings (1972) indicates Quaternary displacement along the entire length of the Arroyo Parida - Santa Ana fault.

B r a d l e y   C a n y o n - Worts (1951) shows the Bradley Canyon fault trending north-northwest for approximately 5 miles near the east end of the Santa Maria Valley. The existence of a fault is based on the alignment of a fault cutting Pleistocene terrace deposits on the north side of the Santa Maria River with the straight course of Bradley Canyon to the south. Approximately 60 feet of displacement of water bearing late Pliocene to lower Pleistocene sediments is indicated. Recent river deposits are not displaced according to a cross section in Worts (1951). No evidence of fault displacement of older, consolidated rocks north and south of the Bradley Canyon fault is indicated (Jennings, 1959).

C a r p i n t e r i a - The Carpinteria fault parallels the shore for 3 miles southeast of Carpinteria and intersects the coast; it is aligned with the Mesa fault at Santa Barbara to the west. This fault forms the south boundary of the Carpinteria Basin. A minimum of 3000 feet of late Pliocene to Pleistocene sediments are downdropped against Miocene sediments on the south side (Dibblee, 1966). Older Quaternary alluvium, consisting of loosely consolidated sand is displaced along the fault.

G o l e t a - The Goleta fault is one of several faults which have been mapped by Hill (1932) and Dibblee (1966) in the foothills north and west of the Goleta Valley. Others assigned to this group and described in detail on succeeding pages are: Carneros, Dos Pueblos, Eagle, Glen Anne, Las Varas, Modoc, Refugio, San Antonio, San Jose and San Pedro. According to Hill (1932) topographic evidence of these faults is lacking.

The Goleta fault trends east-west 3 miles along the north side of Goleta Valley. The west end is aligned with the Glen Anne fault. Upson (1951) indicates that the fault displaces old alluvium of Pleistocene age against late Pliocene to Pleistocene sediments. Upson's (1951) map indicates that old alluvium is tilted 60 degrees next to the fault trace.

M i s s i o n R i d g e - The Mission Ridge fault trends east-west for 5 miles directly north of Santa Barbara. The eastern continuation is covered by alluvium; however, the east end is aligned with the Arroyo Parida fault. The structure at the western end is obscured by alluvium; Dibblee (1966) shows a sinuous trace covered by alluvium continuing west as the More Ranch fault. A curve in the trace occurs at the probable intersection with the San Jose, Modoc and Mesa faults. Dibblee (1966) indicates a maximum of 1500 feet of vertical displacement of lower Miocene sediments with the north side down. Pleistocene fanglomerates on Mission Ridge have been elevated as much as 820 feet (250 meters) in the south block of the fault; the steep scarp north of Mission Ridge is assumed to mark the position of the fault trace (Olsen, 1972). Locally the Pleistocene fanglomerate on Mission Ridge is tilted as much as 35 degrees, probably as a result of movement on the Mission Ridge fault (Dibblee, 1966), and cross sections in Muir (1968) show displacement of late Pliocene to lower Pleistocene water bearing sediments and Pleistocene alluvium.

R e d M o u n t a i n - The Red Mountain fault has a sinuous, generally east-west trace for 13 miles along the south side of Red Mountain and Rincon Mountain (Putnam, 1942). Jennings (1972) indicates that the Red Mountain fault extends west for 25 miles beneath the ocean south of Santa Barbara. The north side of the fault is upthrown with about 20,000 feet of displacement (Stewart, 1943).

Displaced Pleistocene marine terraces and arched Ventura River terraces indicate geologically recent movement (Putnam, 1942), and Jennings (1972) shows Quaternary rocks displaced along the Red Mountain fault. Based on comparison of elevations across the Red Mountain fault in 1957 and 1971, Willott (1972) determined 1.3 to 2.0 cm of displacement, the north block having moved up. A magnitude 6.0 earthquake which occurred in 1941 (California

Department of Water Resources, 1964) may have been situated on the offshore extension of the Red Mountain fault (Sylvester, 1970).

R i n c o n C r e e k - The Rincon Creek fault extends east from the coast near Sand Point in the Carpinteria area into Ventura County. According to Jennings and Strand (1969), the eastern end intersects the Red Mountain fault 12 miles east-southeast of Santa Barbara County. The Rincon Creek fault is aligned with the Mesa fault which intersects the coast at Santa Barbara 9 miles to the west. Analysis of subsurface data revealed the position of the fault and 3000 to 5000 feet of displacement (Lian, 1952). Pleistocene terrace deposits are displaced along the fault, the south block having moved up. Jennings' (1972) map is too small a scale to differentiate the Rincon Creek fault and the Carpinteria fault one-half mile to the south; he combines these two faults into the Carpinteria fault and indicates that the fault has had Quaternary displacement.

S a n J o s e - The San Jose fault is another of several located in the foothills north and west of Goleta. It trends in a northwesterly direction and has a length of approximately 9 miles including the possible concealed southeasterly extension to the north end of the Mesa fault. It is the only one of the group indicated by Jennings (1972) to have Quaternary displacement. According to Dibblee (1966), the south block of the San Jose fault is elevated so that it forms a small north facing scarp in Pleistocene fanglomerate. According to Hill (1932), there has been 1550 feet horizontal and 775 feet vertical movement with the south side up relative to the north.

Inactive - The following faults are considered inactive (no movement in last 500,000 years) as defined in the previous section, Fundamentals of Engineering Seismology.

C a r n e r o s - The Carneros fault (Cameros fault of Dibblee 1966) is one of the several Goleta Valley faults. It tends in an east-west direction and according to Hill (1932) has 13,000 and 1600 feet of horizontal and vertical displacement with the south side up. Upson (1951) indicates that the eastern extensions of the Carneros and Glen Anne faults cut water bearing sediments of late Pliocene and Pleistocene age beneath Goleta Valley. The existance of the faults is based on differences in water level and the lack of the transmission of pumping effects in wells on opposite sides of the inferred fault trace.

C a m u e s a - The northwest trending Camuesa fault is located in the San Rafael Mountains in central Santa Barbara County and has a length of 23 miles. Jennings (1972) indicates that the

Camuesa fault has had no recognized Quaternary displacement. According to Jennings and Strand (1969), the youngest rocks displaced along the Camuesa fault are middle Miocene sediments.

Dos Pueblos - One of Goleta Valley faults. Extends in westerly direction from Tecolote Canyon to the sea at El Capitan. Approximately 400 feet of vertical displacement with the north side up.

Eagle - South of and similar to Dos Pueblos fault. Estimated 9000 feet of horizontal and 500 feet of vertical movement with south side up.

East Huasna - The East Huasna fault has been traced 50 miles from the Santa Lucia Range in San Luis Obispo County southeast into the San Rafael Mountains in Santa Barbara County. Hall and Corbato (1967) indicate a maximum of approximately 1200 feet of vertical displacement; the youngest rocks displaced are of late Miocene age. According to Jennings (1972), the fault has no recognized Quaternary or historic movement.

Erburu - Short east-west coastal fault (1 mile) crosses Las Flores Canyon west of El Capitan Beach. Cuts Rincon and Monterey formations with south side up relative to north.

Glen Anne - One of Goleta Valley faults. Extends in easterly direction from Tecolote Canyon to Carneros Creek and probably beneath alluvium to Goleta. Approximate movement is 1800 feet horizontal and 1000 feet vertical. A geologic investigation by Glenn A. Brown and Associates (1971) for a proposed reservoir site east of Bartlett Canyon indicated that "trenching indicates that the Glen Anne fault has affected the Terrace Deposits" and thus the fault might be considered potentially active.

Hildreth - The Hildreth fault trends west-northwest 13 miles in the San Rafael Mountains of west-central Santa Barbara County. The Big Pine fault terminates the Hildreth fault at the northwest end, and the Hildreth fault abuts the Munson Creek fault at its southeast end. The youngest rocks displaced by the Hildreth fault are of middle Miocene age (Vedder et al., 1967). According to Jennings (1972), there is no evidence of Quaternary displacement along the Hildreth fault.

Honda - The Honda fault trends east-west from near the coast at Point Perdernales, 7 miles along the north slope of the Santa Ynez Mountains. According to Dibblee (1950), the youngest rocks displaced are of middle to late Miocene age. Terrace deposits of late Pleistocene age rest unconformably across the fault and are

not displaced (Dibblee, 1950; Jennings, 1972). Willott (1972) analyzed elevation data along a level line surveyed in 1957-60 and 1971 across the Honda fault; he found no evidence of vertical movement.

L a s V a r a s - One of Goleta Valley faults. The fault is mapped but unnamed by Dibblee (1966) and extends east from Dos Pueblos Canyon and its intersection with the Eagle fault to Bell Canyon (3.5 miles). A concealed fault beneath alluvium shown on Upson's (1951) map in the Goleta area, may be the easterly extension of the Las Varas fault. Displacement on the fault is approximately 1500 feet horizontal and 850 feet vertical with the south side up.

L a v i g i a - The Lavigia fault trends northwest 4-1/2 miles between Goleta and Santa Barbara. The north end is truncated by the More Ranch fault, and the south end is covered by old alluvium near the coast. Well data near the center of the fault indicate a minimum of 2100 feet of vertical displacement of late Pliocene to Pleistocene sediments, the north side having moved down. The displacement dies out to the southeast; the fault is not exposed in bedrock beneath old alluvium in the sea cliff southeast of the mapped end of the fault (Dibblee, 1966). According to Dibblee (1966) the fault is not expressed topographically. Jennings (1972) indicates that Quaternary displacement has occurred along the Lavigia fault.

L i o n ' s H e a d - The northwest trending Lion's Head fault has been mapped from the coast south of Point Sal 5 miles into the Solomon Hills (Woodring et al., 1950). The youngest sediments displaced are late Miocene to early Pliocene in age. The map and cross section prepared by Woodring et al. (1950) suggest 6000-7000 feet of displacement. Pleistocene terrace deposits resting across the fault are not displaced (Woodring et al., 1950), and Jennings (1972) indicates no Quaternary displacement. However, comparison of elevations surveyed in 1957-60 and 1971 indicates an abrupt 0.7 cm change in elevation across the approximate location of the Lion's Head fault; the south side is down similar to the older displacement (Willott, 1972). Changes in elevation along level lines across faults are probably not sufficient to establish that a fault is active (Lamar and Lamar, 1973). It would be desirable to trench the terrace deposits to verify that they are not displaced.

L i t t l e P i n e & L o m a A l t a - The Little Pine fault is a major northwest trending reverse fault along which the Little Pine Mountain block of the San Rafael Mountains has been uplifted (Dibblee, 1966). The Little Pine fault has a sinuous

trace which extends 36 miles from central Santa Barbara County southeast to intersect a strand of the Santa Ynez fault system (Juncal Camp fault). Over much of its length the elevated northeastern block of the Little Pine fault forms a steep, abrupt mountain front. Jennings (1972) indicates that a portion of the Little Pine fault and a 3 mile long branch called the Loma Alta fault displace Quaternary sediments. Dibblee (1966) shows sediments of late Pliocene to early Pleistocene along much of the down dropped southwest side of the Little Pine fault. The maximum displacement of late Pliocene to early Pleistocene sediments indicated by Dibblee (1950) is 4000 feet.

L o m p o c   T e r r a c e - Evenson and Miller (1963) have described an east-west trending ground water basin beneath Lompoc Terrace on the Point Arguello Naval Missile Facility (Vandenberg). The geologic structure is largely obscured by Pleistocene windblown sand; however, the available data suggest that the basin is bounded on the south and possibly the north by east-west trending faults. The maximum length of faulting indicated by Evenson and Miller (1963) is 5-1/2 miles; the faults may continue to the west beneath the ocean. Well data indicate that about 1000 feet of poorly consolidated water bearing upper Pliocene to lower Pleistocene sediments are downdropped between older consolidated early Pliocene and late Miocene sedimentary rocks. Surface evidence of faulting in older rocks on the south side of the basin is described by Evenson and Miller (1963). The faults are overlain by Pleistocene sand, and no evidence of geologically recent movement is known.

M o d o c - The Modoc fault trends northwest 1-1/2 miles between the Goleta and More Ranch faults; ground water data summarized above is the only evidence for its existence given by Upson (1951). Several other minor, unnamed faults are shown on Upson's (1951) geologic map.

M o n t e c i t o - The Montecito fault was a previously unmapped fault and its presence in the Montecito area was postulated on the basis of drilling records obtained in an investigation by Geo Technical Consultants, Inc. (1974). They indicate the fault is vertical with the north side up and displacement on the order of several hundred feet. On the basis of their statement "Recent activity of this fault can be seen in offset terrace deposits and alluvium west of Montecito", the fault should be regarded with suspicion and considered as possibly or potentially active, similar to other related faults in the South Coast region.

M o r a l e s - The Morales fault is a thrust fault with a length of 35 miles. It trends northwest through the Caliente Range north

of Santa Barbara County. At the north edge of Cuyama Valley the fault curves into a slightly sinuous east trending trace which parallels the north edge of the valley. Jennings and Strand (1969) show the trace extending east to within 3 miles of the San Andreas fault. At its closest point the fault lies directly opposite the Santa Barbara County boundary, along the north bank of the Cuyama River.

Schwade (1954) shows 6000 to 9000 feet of displacement on the Morales fault; upper Miocene and older sediments are thrust over late Pliocene rocks. These younger sediments fill the lowlands of Cuyama Valley. The Caliente Mountains to the north have been uplifted along the fault, and the trace is situated at the base of the mountains. Cross sections prepared by Schwade (1954) show Recent alluvial sediments as conformable (no discordance in structure) with the underlying late Pliocene sediments; thus, the sediments filling Cuyama Valley could have been deposited during a period of continuous deposition and fault uplift of adjacent highlands from the late Pliocene through Recent time. However, study of 1:120,000 scale color IR air photographs indicates no physiographic evidence of geologically recent displacement, and Jennings (1972) indicates that the Morales fault lacks recognized Quaternary and younger movement. Any physiographic evidence of displacement would be quickly obliterated at the base of a mountain; trenching across the fault trace would be required to verify that no rocks younger than late Pliocene have been displaced.

M u n s o n C r e e k - The Munson Creek fault has a generally east-west, sinuous trace for 25 miles from west-central Santa Barbara County into central Ventura County. According to Fisher and Dibblee (1961), the 10 mile long, east-northeast trending segment of the Munson Creek fault in Santa Barbara County has had several thousand feet of horizontal displacement. This segment of the Munson Creek fault is aligned with the active eastern portion of the Big Pine fault to the northeast and with a east-northeast trending segment of the Santa Ynez fault to the southwest. Fisher and Dibblee (1961) believe that these faults are all characterized by a major component of horizontal displacement: their alignment suggests that they originated as a result of horizontal movement on a continuous shear zone within ancient basement rocks beneath the thick cover of sedimentary strata. The great thickness of the sedimentary sequence in this area may account for the lack of a continuous surface break along the postulated deep shear zone. Under Fisher and Dibblee's (1961) hypothesis the segment of the Munson Creek fault in Santa Barbara County should be considered as active as the Big Pine fault to the northeast and Santa Ynez fault to the southwest. However, the youngest rocks displaced along the Munson Creek fault are lower Miocene in age, and

Jennings (1972) indicates that there is no evidence of Quaternary movement.

O z e n a - The northwest trending Ozena fault is south of - and en echelon to - the South Cuyama fault; its trace extends for 25 miles on the northeast slope of the Sierra Madre Mountains. The southern portion of the trace underlies the headwaters of the Cuyama River, and the south end of the Ozena fault abuts the Big Pine fault. Larsen (1958) suggests that the principal movement was prelate Miocene or slightly later, prior to truncation by the Big Pine fault. The youngest rocks shown displaced on Madsen's (1958) map are middle Miocene sediments; he shows the fault overlain unconformably by folded upper Miocene sediments. Jennings (1972) indicated that the Ozena fault has no recognized Quaternary movement.

P e z z o n i - Woodring _et al_. (1950) mapped the northwest trending Pezzoni fault over a distance of 4 miles in the Solomon Hills directly south of the Santa Maria Valley; the northwesterly end is obscured by old sand dunes. Fault displacement and down folding of 5000-6000 feet of the late Miocene to early Pliocene sediments is indicated on a cross section prepared by Woodring _et al_. (1950). No evidence of Quaternary or historic movement is indicated by Jennings (1972).

R e f u g i o - This fault trends in an east-west direction along the south side of the Santa Ynez Mountains about 1/2 mile north of the coast in the El Capitan - Refugio coastal area. The south side of the fault is up relative to the north; vertical displacement is about 500 feet with no apparent horizontal movement.

S a n A n t o n i o - The San Antonio fault is located in the low foothills north of Goleta. It makes a prominent concave (north) trace and truncates the southeast trending Ygnacio fault. The south side is up and the approximate displacement is 500 feet vertical.

S a n P e d r o - The San Pedro fault is south of (4000±) and parallels the San Jose fault in the foothills north of Goleta. Displacement is approximately 1500 feet horizontal and 500 feet vertical with the south side up relative to the north. This fault is equivalent to the San Jose B fault of Hill (1932).

S a n t a M a r i a - As indicated by Worts (1951) the Santa Maria fault trends 7 miles north-northwest beneath the City of Santa Maria. A cross section prepared by Worts (1951) indicates 150 feet of displacement of late Pliocene to early Pleistocene water bearing sediments; the Recent river deposits beneath the

Santa Maria Valley are not displaced. On the basis of oil well data, Canfield (1939) shows approximately 400 feet of displacement of lower Pliocene sediments on the Santa Maria fault. No evidence of faulting north and south of the Santa Maria fault is indicated in the older rocks exposed in the uplands adjacent to Santa Maria Valley.

S o u t h C u y a m a - The South Cuyama fault trends northwest for 37 miles along the south side of Cuyama Valley and dies out south of the town of Cuyama (Jennings and Strand, 1969). Earlier workers (Schwade, 1954; Schwade et al., 1958; Hill et al., 1958) considered this fault to be the southeast extension of the Nacimiento fault, previously discussed. Older Cretaceous and Tertiary sediments of the Sierra Madre Mountains are faulted against younger, downdropped sediments filling Cuyama Valley.

Schwade (1954) shows 3500 to 5000 feet of fault displacement of the late Pliocene in Cuyama Valley. The South Cuyama fault is similar to the Morales fault in that the geologic and geomorphic data suggest fault movement from the late Pliocene possibly through Recent time. Jennings (1972) shows the South Cuyama fault displacing Quaternary rocks north of its intersection with the Whiterock fault. In this area Schwade (1954) indicates Cretaceous sediments faulted against Quaternary terrace deposits. To the southeast of the intersection with the Whiterock fault, Madsen (1959) and Jennings (1972) show no displacement of Quaternary deposits along the South Cuyama fault. The South Cuyama fault is situated at the base of the Sierra Madre Mountains where evidence of geologically recent displacement could be obliterated by rapid erosion and deposition. However, study of 1:120,000 scale air photographs indicates no evidence of geologically recent movement, and the fault trace is irregular. The terrace deposits have the appearance of being deposited against an old fault scarp and may not be displaced. Fault displacement of terrace deposits should be verified before this fault is classified as potentially active.

S u e y - The Suey fault extends from the Sisquoc River 18 miles northwest to the north boundary of Santa Barbara County at the Cuyama River. Hall and Corbato (1967) suggest that the Suey fault continues northwest into San Luis Obispo County as a branch of the West Huasna fault which extends another 16 miles to a point opposite San Luis Obispo Bay. The youngest rock unit displaced by the Suey fault is late Miocene in age. The amount of displacement is not known in Santa Barbara County; to the northwest in San Luis Obispo County, Hall and Corbato (1967) have estimated 750 feet of possible post late Miocene horizontal movement. No evidence of Quaternary or historic movement is indicated by Jennings (1972).

W h i t e r o c k - The 17 mile long Whiterock fault is situated 2 miles west of the Morales fault in the Caliente Range north of Santa Barbara County. Within Santa Barbara County the fault trends northwest, obliquely across the western portion of Cuyama Valley. On the south side of Cuyama Valley the Whiterock fault intersects the South Cuyama fault. Schwade (1954) and Schwade *et al*. (1958) show 5000 feet of displacement of late Pliocene sediments along the Whiterock fault in the Russell Ranch Oil Field at the north edge of Santa Barbara County. Within Cuyama Valley Jennings and Strand (1969) show the Whiterock fault covered by Pleistocene and more recent sediments, and according to Jennings (1972) there is no evidence of Quaternary movement on the Whiterock fault.

Y g n a c i o - This fault is another of the Goleta Valley faults; it is located about three miles north of Goleta. It trends in a southeasterly direction and is truncated by the arcuate San Antonio fault. The north side is up and approximate displacement is 1500 feet horizontal and 800 feet vertical.

SEISMIC ZONING

Zoning for seismic hazards should consider all adverse aspects of seismic events. These include ground surface rupture along the fault, ground shaking due to the propagation of seismic shock waves, liquefaction of saturated soil, settlement of granular soils due to seismic densification, seismically-induced landslides, and generation of tsunamis. This section of the report concerns only the first two factors - ground surface rupture and ground shaking. Other adverse effects of earthquakes are treated under separate sections and their effects on land use planning are taken into account separately.

Because of the scale of the study and the fact that data on seismic hazards are limited, seismic zoning can best be based on a statistical approach. When planning reaches the design stage, more specific data must be acquired and more consideration given to the specific site conditions. This is particularly true for large or critical structures such as high occupancy buildings, schools, hospitals, and the like.

Ground Rupture

The ground surface rupture along a fault, although limited in area, is disastrous when it occurs under a structure, particularly dams (see item 9 under Recommendation for Future Study). Engineering design can do little to accommodate such movement, and for practical purposes, the only solution is to avoid location on a fault.

For planning or design of projects in or near a fault zone, several aspects of the fault must be considered. First, the character of the fault must be known. Is it a broad zone of interbraided fractures or a localized gouge zone? Is the fault zone a single line or does it have a series of branches or offshoots? Second, the exact location of the fault breaks must be determined in relation to the proposed structure site. When several breaks are known to exist, the relative age of the individual breaks should be determined whenever possible. Finally, it is necessary to determine to some degree the probability of movement during the life of the structure. The probability of movement on an inactive fault is very low and would not normally prevent building anything but the most critical structures across the fault. In the case of an active fault that has a number of different traces, the last previous break has a much higher probability of movement than some of the older breaks.

All known active faults of significance are shown on the Seismic - Tectonic Map along with a classification of their activity. The accuracy of their location will vary somewhat depending on the scale of the base map from which they were obtained and the degree of interpretation contained in the original work. However, we feel that the fault locations generally are accurate enough for planning purposes. For project design, it will be necessary in almost all cases to conduct specific site studies in order to determine the fault location more accurately. Also, future studies will almost surely result in the discovery of presently unknown faults and reclassification or relocation of some known faults.

Because of the extreme linear nature of faults, no ground rupture rating has been used for the fault zones. Instead, the following guidelines are recommended for planning and construction of projects which are located in close proximity to known faults.

Historically Active and Active Faults - No structures of consequence should be constructed within fifty feet of the fault trace, except those structures which cannot be relocated to avoid the fault. This would include projects such as highways, bridges, utilities, and the like.

Potentially Active Faults - Major or critical structures such as schools, hospitals, police stations, or communications facilities should not be constructed within fifty feet of a fault trace. All other types of structures should be planned to avoid a location on a fault insofar as practical.

Inactive Faults - Ground rupture should create no constraints on location of structures on inactive faults, except for an investigation to confirm that the fault is inactive. The ancient fault

movement might have produced certain adverse foundation conditions, such as high ground water, weak gouge zones, or abrupt changes in bearing capacity. Thus, a more extensive foundation investigation can be anticipated for a site located on an inactive fault, even though the defects are not related to future ground rupture.

Ground Shaking

The severity of ground shaking at a specific site is dependent on the following items:

(1) The source mechanism which initiates the energy release. This is commonly described in terms of the Richter magnitude of the earthquake.

(2) Energy attenuation in the bedrock during wave transmission between the earthquake focus and the site. This is a function of the distance between these two points, the type of rock, and the geologic structure of the bedrock. Distance is probably the most important factor.

(3) Bedrock geometry at the site. This is determined largely by the subsurface or surface bedrock topography.

(4) Soil properties, if soil is present at the site.

In this study, the potential energy release in item number (1) has been determined by correlation with the total mapped fault length using Housner's relationship described earlier on Figure 9. Items (2), (3), and (4) have been lumped together statistically, and are determined from the magnitude of the maximum probable earthquake and the distance from the fault in accordance with Davenport's (1972) method, also described earlier in this report. However, these procedures do not directly consider the historic seismic shocks to be expected rather than the maximum magnitude that can reasonably be expected. Also, the historic seismicity covers too short a time span to provide a good basis for prediction of future shocks.

It has been observed that the length of the ground rupture associated with an earthquake ranges from 20% to 50% of the total fault length (Albee and Smith, 1966). The maximum credible earthquake has thus been taken as one which ruptures along 50% of the total fault length. This provides an earthquake magnitude as great as could reasonably be anticipated at any time in the future for the specific fault under consideration. Sometimes an earthquake of this magnitude is used for design against collapse of important structures, but is not a suitable parameter for zoning studies because the maximum credible earthquake in most cases has

a very low probability of occurrence during a normal building's life. For a fault with a high strain rate like the San Andreas, this probability may be as high as 25% for a 50 to 100 year project life; but for some other active faults in the County, this probability may be only about one to two percent. For this reason, it is more reasonable to use a lesser earthquake for land use planning and zoning.

The maximum probable earthquake is defined as the maximum size earthquake that could reasonably be expected to occur during a project's life. If adequate data were available to calculate recurrence intervals for all the major faults in the County, it would be a fairly straightforward task to select a standard probability of occurrence and to calculate the maximum probable earthquake for this condition. Unfortunately, there are only two faults affecting the study area for which sufficient data are available to calculate recurrence intervals - the San Andreas and the Big Pine faults. Consequently, it is necessary to rely on another method to determine the maximum probable earthquake, which - for planning and zoning purposes - has been defined as one that would produce a fault rupture along 25% of the total length of the fault. As was done in the case for the maximum credible earthquake, the magnitude of the earthquake was determined using Housner's (1969) relationship between magnitude and rupture length. The validity of this approach is verified by data for the San Andreas fault for which we have the most abundant and reliable data on recurrence interval, but the method proves somewhat conservative for the Big Pine fault and probably even more conservative for some of the other faults in the County.

In preparing the Seismic-Tectonic Map, the hazard of ground shaking has been equated to peak ground acceleration. Although the duration and spectral content of the shaking are also important factors in the determination of damage due to ground shaking, they have not been included in the overall rating, because there is no common means of including these factors for general planning purposes. Therefore, the peak acceleration should be regarded as an index of the intensity, but not - by itself or without modification - as a design factor. The County has been subdivided into four zones of increasing risk, based on peak ground acceleation. The expected maximum ground acceleration in each of the zones is tabulated below.

Zone I	Less than 20% of gravity
Zone II	20% to 50% of gravity
Zone III	50% to 70% of gravity
Zone IV	Greater than 70% of gravity

The zone limits were established by calculations based primarily on Davenport's (1972) relationship between magnitude and peak acceleration. In applying these values to zoning concepts, Davenport has calculated an uncertainty factor on the order of 1.5 to allow for the uncertainties associated with the geotechnical character of the intervening rock and soil. Where this factor augments the calculated peak acceleration, it could shift the particular site to the next higher zone. This condition is recognized in the assignment of the variability number (second digit of the hazard rating number). Applying the uncertainty factor to a particular site in Zone II, for example, could shift the seismic intensity to a value corresponding to that of Zone III. Consequently, the assigned primary rating of 2 for this zone is followed by a 6 variability number, which means that after applying the Davenport's uncertainty factor, the primary rating could shift to a 1 (low) or a 3 (high). Zone IV covers areas which are so close to a major fault that a transition from a 3 rating to a 2 rating is very improbable even with the application of the uncertainty factor, consequently a hazard rating number of 31 (high with no variation) has been assigned to this zone.

The fault shown on the Seismic-Tectonic Map as the westerly extension of the Big Pine fault is not shown on any published geologic maps, but there is a strong linearity visible on the Earth Resource Technology Satellite (ERTS) photographs. This, coupled with the historic strong earthquakes felt in the Los Alamos area, was sufficient in our opinion to locate an historically active fault down San Antonio Canyon and to include its effects in the seismic zoning. There presently is an on-going investigation of this major fault, which may confirm or deny its existence.

As can be seen from the Seismic-Tectonic Map, the zones are determined by the four major faults in or adjacent to Santa Barbara County. These faults are the San Andreas, the Santa Ynez, the Big Pine (including the westerly extension), and Nacimiento faults. Somewhat smaller faults, located closer to the metropolitan area, such as the More Ranch - Mission Ridge - Arroyo Parida fault and the San Jose - Mesa fault, are overshadowed by an adjacent larger fault, such as the Santa Ynez fault. Even areas located very close to the epicenter of a maximum probable earthquake on one of the smaller faults would experience a ground acceleration which would not exceed that resulting from the more distant larger earthquake. Nevertheless, these smaller faults should not be ignored, because they increase the probability that any given degree of ground shaking will occur.

Due to the distribution of large faults throughout the County, there is no area that is presently classified as Zone I. However, if the westerly extension of the Big Pine fault is not considered,

a relatively small area west and south of Santa Maria would fall into this zone. A majority of the County, including the metropolitan South Coast area, is situated in Zone III. The Santa Maria and Lompoc areas are located in Zone II, although Lompoc is situated in narrow strip of Zone II between two broad Zone III areas. None of the developed areas of the County is located in Zone IV.

TSUNAMIS AND SEICHES

Tsunamis are sea waves - sometimes erroneously referred to as "tidal waves" - which are caused by submarine or coastline earthquakes. These are relatively low and harmless in the open ocean, but can reach substantial heights when they approach shallow water depths near shore. They can travel hundreds and even thousands of miles and maintain enough energy to be destructive. Seiches are waves which are generated in an inland body of water by earthquakes.

Risk from a tsunami (seismic sea wave) to installations and developments on or near the coast of Santa Barbara County undoubtedly exists, and must be considered in prudent planning. However, an alarmist attitude calling for extreme precautions is not justified, on the basis of what is known of the circumstances of such occurrences in all parts of the world, and on the few and partly doubtful records and reports of such occurrences on this coast.

Such waves have been known to rise to great heights - 50 or even 100 feet - on the coasts of Japan, South America, Alaska and Hawaii. These wave heights are associated with very rapid shallowing of the ocean bottom toward the coast. Off Japan, South America and Alaska, the tsunami waves originate in association with deep submarine troughs - the Japan Trench, Atacama Deep, Aleutian Trench, etc., and reach extreme heights on the nearest coast. On Hawaii, a similar effect is producted by sudden rising of the ocean floor as one approaches the islands, and has repeatedly produced coastal flooding on the arrival of seismic sea waves originating from the distant earth movement.

No such abrupt shallowing of the ocean toward the coast exists in Southern California, and there is no oceanic trough off this coast. Consequently, effects of tsunami waves due to distant earthquakes have been limited to a rise of a few feet, sufficient at worst to swamp or damage small craft. Waves during local storms, or the high surf occasionally set up by waves originating in storm centers far out in the Pacific present a more serious and more frequent hazard.

On many coasts, waves of tsunami type are occasionally observed associated with moderately large earthquakes originating

comparatively close inshore. While these are limited and local events, compared with the great seismic sea waves that sweep over the ocean, they may present a serious local risk.

On the Southern California coast, we know of one event of this kind which is well documented, and another, the reports of which have been much discussed pro and con as to whether such a seismic sea wave did occur. On November 4, 1927, a major earthquake originated off the coast opposite Point Arguello. The shaking on shore was noteworthy; there was damage at Lompoc, and the tracks of the coastal route of the Southern Pacific Railroad were so disturbed that train service was interrupted until major repairs could be completed. A true tsunami of relatively small amplitude occurred; it was recorded on tide gages as far away as Hawaii, and reached heights of six feet above mean tide level on the west coasts of Santa Barbara and San Luis Obispo Counties.

On December 21, 1812, an earthquake damaged the Mission installations increasingly from San Fernando westward to Purisima (near Lompoc), which was largely demolished, and was afterwards rebuilt on a different site. The available chronicles and histories include several reports of waves occasioned on the coast of the Santa Barbara Channel, all of which have been questioned. In various versions, there are three principal accounts.

(1) A ship at anchor off Gaviota was disturbed by the wave which was observed to pass to the shore and splash up visibly in the canyons. The latter remark led the late Professor Louderback, from consideration of the contours and general topography, to infer that the splash might have reached a height of 50 feet. More recent students have been reluctant to accept this conclusion.

(2) A small smuggling vessel in the harbor at Refugio (west of Goleta) is said to have been carried an unspecified distance up the canyon and returned when the wave subsided. This account may be found in Bancroft's historical works, for example, but rests on questionable authority, although it is said to be taken from the captain's log.

(3) Several descriptions of the earthquake, largely at second hand state that there was a high wave at Santa Barbara. Apparently, the Mission chronicles do not confirm this. Rather, they indicate that the strong earthquake was felt, and thereupon, the populace retired to higher ground in anticipation of a wave which did not materialize.

Apart from the doubtful height of 50 feet at Gaviota, there is nothing in these reports which is inconsistent with a wave of small

height, like that of 1927. Such a wave might have been started by an earthquake originating under the Santa Barbara Channel, or even on the islands. The possibility of another similar occurrence cannot be rejected.

There are five major areas along the Santa Barbara Coast which are subject to inundation by a tsunami if an earthquake were to occur off shore. These areas are Point Sal at the mouth of the Santa Maria River, the mouth of the Santa Ynez River west of Lompoc, Goleta Slough - Santa Barbara Airport area, Santa Barbara City - Harbor Area, and Carpinteria. Several other but smaller areas at the mouths of major streams, such as the beaches at Refugio, El Capitan and Gaviota, would also be susceptible to inundation. These are located in lowland areas along the coast.

In planning of all coastal installations and developments, it is recommended that a 10-foot high sea wave be considered and that a conservative contour elevation of 40 be used as a basis for establishing the tsunami risk limit. This elevation is somewhat arbitrary and considers the possible limits of run-up in lowland - gentle sloping areas. It does not mean that a high level of destruction would necessarily result at that elevation. Areas lying below the 10-foot contour would be most susceptible to inundation and damage.

Where steep bluffs 15 feet or greater in height are exposed to the ocean along the coast a tsunami threat is not considered serious. These bluffs would act similar to sea walls and would reflect the anticipated maximum 10-foot high sea waves. On the other hand, because of the channeling effect created at some areas where high promontories are present and narrow constricted entry channels are formed, inundation due to run-up could be substantial.

Deciding what precautions to take regarding tsunamis is difficult not only because the degree of hazard is difficult to ascertain but even more because of the very low, unknown frequency of occurrence. Since the recurrence interval for a substantial tsunami is probably greater than the life of structures, and considering the value of coastline property, prohibition of building for this reason does not appear justified. The loss of life factor is of more concern. For major shocks some distance away, there would be sufficent warning for residents to evacuate. A local shock originating in the channel or offshore islands could produce a wave height in Santa Barbara County as large as a distant major shock; it would not likely provide adequate warning. Aside from the fact that much of the low level shoreline is already developed, a large number of people would frequently occupy the beach even if there were few buildings. A tsunami occurring at high tide under storm or high wind conditions would be the most critical.

Santa Barbara County
Tsunamis, Seiches

	Problem Rating	Possible Variation from Assigned Rating
	1. Low	1. No Variation
	2. Moderate	6. ±1 (Low, High)

GUADALUPE
SANTA MARIA
State Route 166
Stowell Rd
Betteravia Rd
BETTERAVIA
Black Rd
Blosser Rd
State Route 1
SANTA MARIA RIVER
Twitchell Reservoir
POINT SAL
ORCUTT
Clark Ave
GAREY
SISQUOC
U.S. Highway 101
CASMALIA
State Route 135
CUYAMA RIVER
NEW CUYAMA
CUYAMA
SAN LUIS OBISPO COUNTY
KERN COUNTY
State Route 33
VENTUCOPA
SISQUOC RIVER
Zaca Lake
LOS PADRES NATIONAL FOREST
LOS ALAMOS
VANDENBERG AIR FORCE BASE
Lompoc Casmalia Road
SURF
Central Ave
LOMPOC
SANTA RITA
LOS OLIVOS
BALLARD
Alamo Pintado Rd
Refugio Rd
Edison
State Route 154
BUELLTON
State Route 246
SOLVANG
SANTA YNEZ
Lake Cachuma
SANTA YNEZ RIVER
VENTURA COUNTY
POINT ARGUELLO
LAS CRUCES
GAVIOTA
POINT CONCEPTION
MONTECITO
Cathedral Oaks Rd
Foothill Rd
State St
East Valley Rd
Hollister Ave
GOLETA
Cliff Dr
SANTA BARBARA
SUMMERLAND
CARPINTERIA
N

Partly because of the relatively low wave height anticipated, and partly because of the low frequency of occurrence tsunamis were given a weighting factor of 19, and areas considered subject to inundation have been rated as moderate with a high to low variability factor (26) up to the approximate 40 foot contour.

Seiches can affect bodies of water as small as swimming pools, but normally would be likely to cause major damage only to developed areas surrounding - or downstream from - large lakes. In addition to small waves initiated by ground shaking which might affect the local shoreline, larger waves can be generated by large landslides triggered by an earthquake. These waves could overtop a dam and cause serious damage to property lying downstream.

There are several lakes in the County, the largest being Lake Cachuma. Except for some recreational facilities, there is little shore development surrounding the lake. Other water bodies subject to seiches are Twitchell and Gibralter Reservoirs, Jameson and Zaca Lakes and Sheffield Dam. Detectable seiches would be more frequent than tsunamis, but generally of less wave height.

LIQUEFACTION

Liquefaction is the almost complete loss of strength of saturated sandy soil accompanying ground shaking during an earthquake. The seismic shock waves densify loose, saturated, granular soil causing a reduction in the pore space between the sand grains. This transfers the intergranular load to the pore water and results in a temporary loss of strength. On relatively level ground this may cause the water to rise to the ground surface, usually carrying sand with it and forming sand "boils", which are familiar features where liquefaction occurs as a result of strong ground motion. On sloping, ground liquefaction will usually result in slope failure such as occurred at the Sheffield Dam in the 1925 Santa Barbara earthquake.

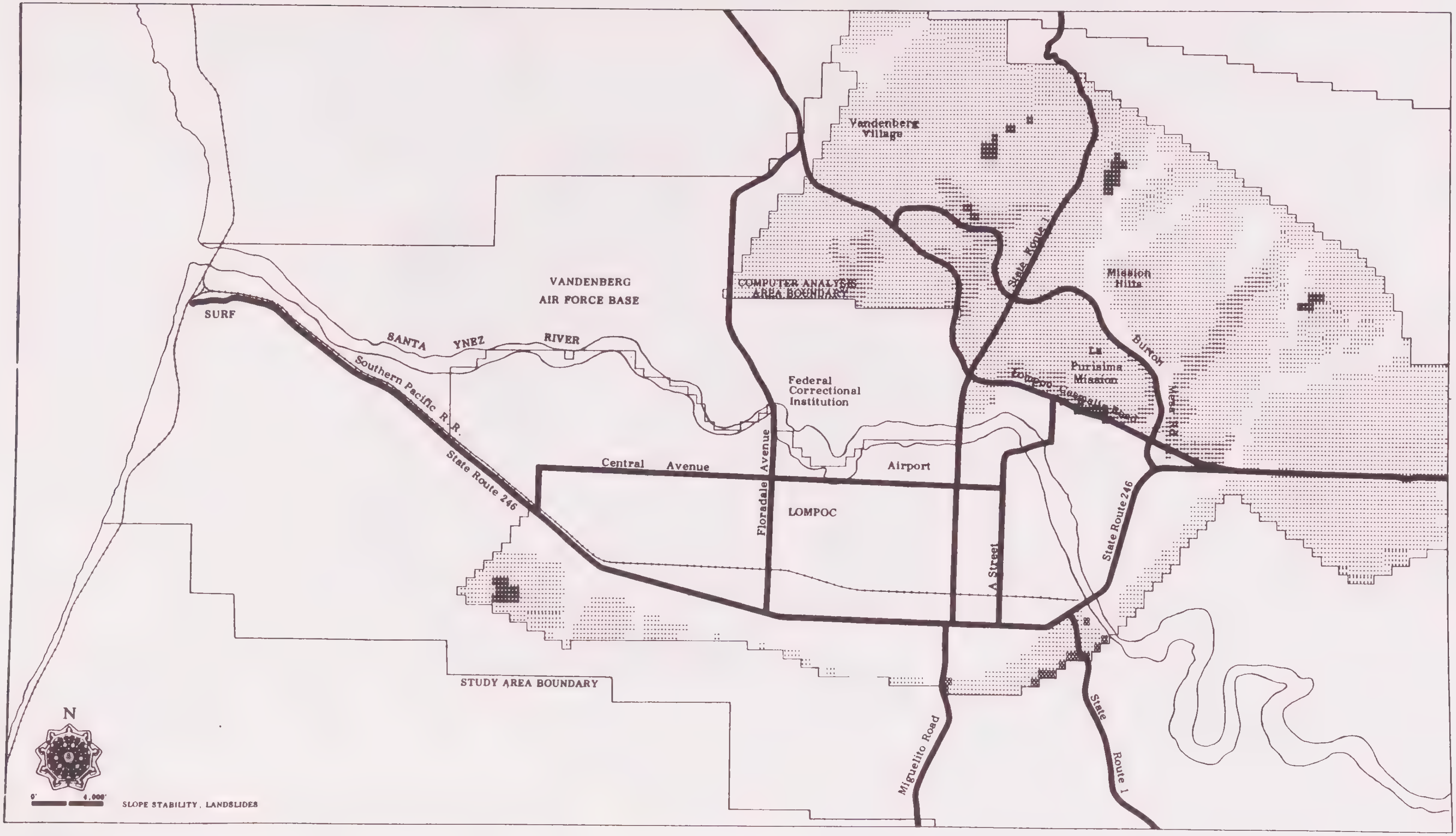
In connection with buildings, the resulting low shear strength and volume reduction can cause extreme settlements or even overturning of structures supported on such soils. The most serious examples of this have occurred in Japan. Damage from liquefaction in the United States was usually overlooked or not considered. It was not until this condition occurred near the Van Norman dam during the San Fernando earthquake of 1971 that real concern about liquefaction increased dramatically in California. It is possible that there has been an over-reaction, but caution is prudent until more experience and data are acquired on liquefaction potential.

Although to our knowledge there is no historic evidence of liquefaction in Santa Barbara County, most of the low coastal plain

COMPUTER ANALYSIS AREA BOUNDARY
STUDY AREA BOUNDARY
HIGHWAY 101
LOS OLIVOS
State Route 154
Pintado Road
Alamo
BALLARD
Base Line Avenue
Refugio Road
Edison St.
SANTA YNEZ
State Route 246
BUELLTON
SOLVANG
State Route 246
Airport
SANTA YNEZ RIVER
Alisal Road
N
0' 4,000'
SLOPE STABILITY, LANDSLIDES

Lompoc Study Area
Slope Stability, Landslides

Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	6. ±1 (Low, High)
3. High	5. -2 (Low)
3. High	3. -1 (Moderate)


Vandenberg Village
Mission Hills
COMPUTER ANALYSIS AREA BOUNDARY
VANDENBERG AIR FORCE BASE
SURF
SANTA YNEZ RIVER
Southern Pacific R.R.
State Route 1
La Purisima Mission
Burton Mesa Rd.
Federal Correctional Institution
Central Avenue
Airport
Floradale Avenue
State Route 246
LOMPOC
A Street
STUDY AREA BOUNDARY
Miguelito Road
State Route 1
N
0'
4,000'
SLOPE STABILITY, LANDSLIDES

Santa Maria-Orcutt Study Area
Slope Stability, Landslides

	Problem Rating	Possible Variation from Assigned Rating
	1. Low	1. No Variation
	1. Low	2. +1 (Moderate)
	1. Low	4. +2 (High)
	2. Moderate	6. ±1 (Low, High)
	3. High	3. -1 (Moderate)

and valley bottoms underlain by alluvium were given a moderate (2) rating with respect to liquefaction potential. This rating was largely based on the probable depth to groundwater with consideration given to probable soil characteristics (i.e., classification, grain size, density) and probable earthquake intensity and duration. The presence of groundwater is one of the key factors in determining liquefaction potential. In the absence of information regarding the relevant soil characteristics, the most reliable data available were groundwater measurements from wells monitored by the United States Geological Survey. Where depth to groundwater is known or reasonably inferred, a variability value of 2 (possibility of being one rating level higher) was applied. Similarly in alluvial areas where the depth to water was uncertain, a rating of 26 (moderate - high to low) was assigned. Liquefaction is not known to occur in areas underlain by bedrock; these areas have been rated low with no variation. Areas in geologically Recent granular materials have been rated low with a possible variation to moderate or high considering a possible localized high perched water condition.

Data regarding grain size and density are generally lacking, so that the potential for liquefaction based on these criteria could not be reliably determined. It was assumed that the soil conditions were moderately conducive to liquefaction where sediments were located below a shallow ground water table.

It has been only relatively recently that testing and analysis for liquefaction has been done (and it is still not common), so there are essentially little or no data for evaluation of the problem. More information is needed regarding the soil and groundwater conditions before a determination of the liquefaction potential can be made for any particular area or site.

The areas considered to be potentially most susceptible to liquefaction are the low coastal areas with high groundwater at Carpenteria (south of the Freeway), the harbor area in Santa Barbara, the Goleta slough, the Santa Barbara airport, and the alluviated valleys along the course of the Santa Ynez River near Solvang, Buellton and Lompoc and along the Santa Maria River near Santa Maria and Guadalupe.

LANDSLIDES AND SLOPE STABILITY

One of the major problems in hillside construction is slope stability. Soil creep, which is a special type of unstable ground condition, is discussed separately. Much of Santa Barbara County is mountainous or hilly with variable and complex geologic conditions; thus slope stability can be a problem in areas of potential

urban development. Concern over this problem tends to be a building and safety rather than a planning function because almost every landslide or potentially unstable area can be corrected given enough money. However, for areas of severe slope stability problems, prevention or correction of landslides can be prohibitively expensive. These problem areas would be prime candidates to be left undeveloped and designated to remain in natural open space, although cost considerations and difficulty of development would probably result in at least some of this land remaining undeveloped in any case.

The stability of slopes is a complex function of the height and steepness of slopes, the inherent strength of the basic material underlying the slopes, and the presence and orientation of geologic planes of weakness such as bedding, joints, and faults. The surface and subsurface moisture conditions, weathering and temporal effects are important factors also in determining slope stability.

Probably the best single indicator of future stability is the past record of slope stability or instability, indicated by the number of existing landslides prior to development. This is a helpful guide, although a particular development could create either stability or instability. Unstable land can be made stable, and stable land can be made unstable, depending on the amount and type of grading. Depending on the exact nature of the problem, slope stability problems or landslides can often be corrected or stabilized by remedial grading involving such techniques as flattening existing slopes, constructing compacted fill shear keys, buttresses or stability blankets, or removing the landslide mass entirely. However, a substantial amount of analysis and engineering design must be done in such cases. This, coupled with the cost of the remedial grading, can make safe development of an existing landslide or a potentially unstable hillside area a very expensive operation.

The evaluation of slope stability was based on all known available data, but because data are scarce in many areas, emphasis was placed on existing landslides in making the ratings. Unfortunately, the existing geologic maps of Santa Barbara County are generally inadequate in terms of landslides because they were prepared with other objectives in mind, i.e., general stratigraphy, structure, and mineral resources.

Although borings are frequently required to identify and delineate ancient landslides, many can be readily identified on at least a tentative basis from the topographic form of the landscape by study of stereographic aerial photographs. Landslides may appear as uneven mounds or terraces on a hillside, often with steep escarpments at their head, and the surface of the slide may have

a disturbed, hummocky appearance. Drainage courses may be disrupted and local areas of ponding may be present. Analysis of aerial photographs was the method used in this study to delineate landslides. The landslides shown on the slope stability maps which are based on aerial photo interpretation are tentative and should be confirmed by test borings or other means of exploration.

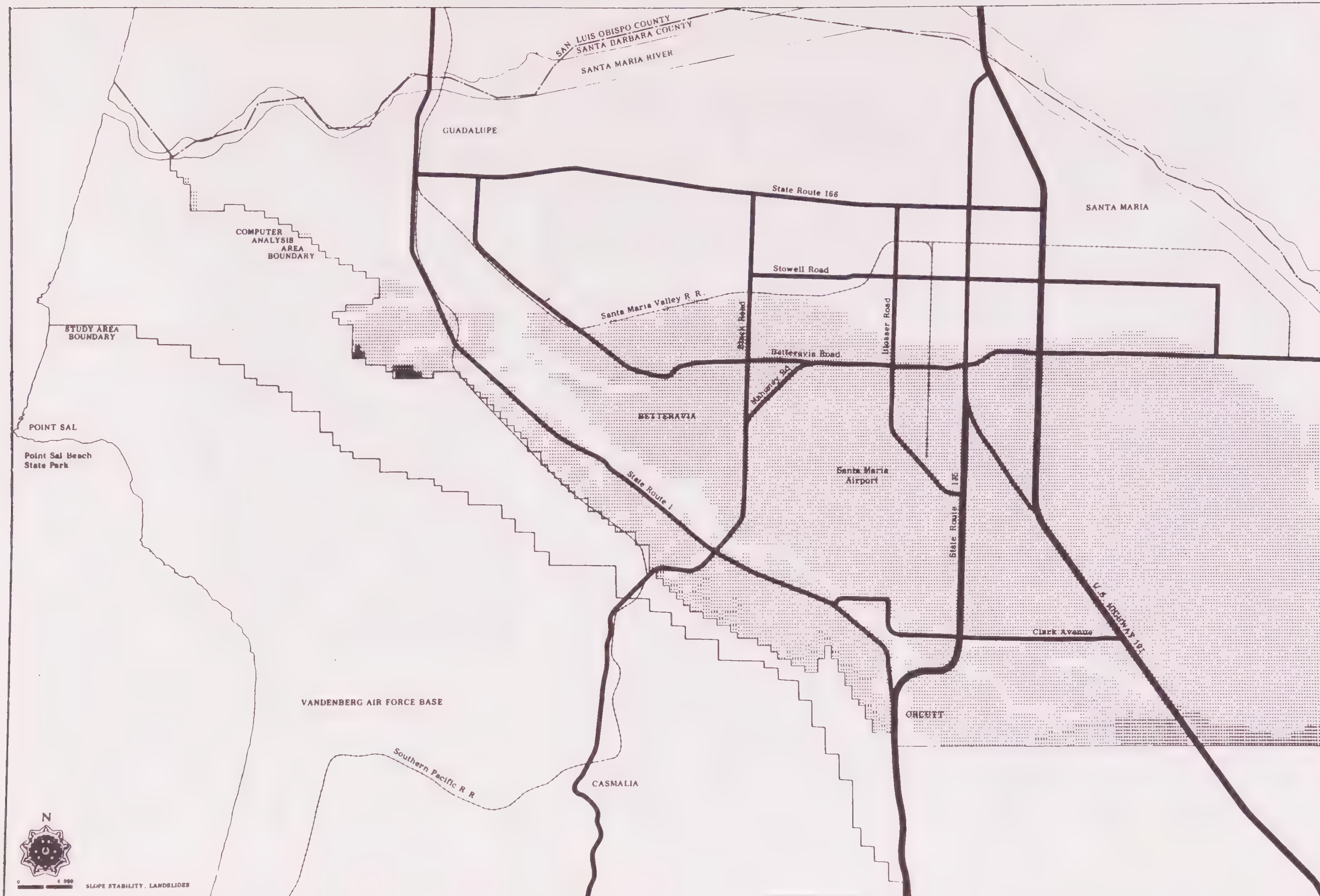
It is also possible that some slides were not detected by this method because they were subtle features, and many are too small to be detected or mapped at the scale used. Therefore, although the slope stability maps prepared in this study are considered satisfactory for land use planning or preliminary feasibility studies, they are not adequate for detailed engineering studies and an investigation should be made for specific projects.

Because of variation in the stability of different geological formations, some are much more prone to landsliding than others. In the County, the formations most susceptible to landsliding are the Rincon, Monterey. Point Sal and serpentines associated with the Franciscan Formation. Of these, the Rincon and Monterey Formations are most often encountered in or near urban areas and have by far the greatest number of landslides associated with them. For this reason, they have been given a high to moderate rating (33) irrespective of the dip of the beds, since geologic structure does not necessarily appear to be the dominant factor in instability. This is slightly more applicable to the Rincon Formation than the Monterey. All originally mapped or photo-mapped landslides were also assigned a slope stability problem rating of 33. Other formations were considered and rated based on engineering characteristics of the formation in that area, the geologic structure (bedding attitudes, absence or presence of faults or jointing), steepness of natural terrain, and occurrence of other recognizable landslides in the area. These ratings can be generalized as follows:

Low (1) - Areas with generally low or no risk. Include flatlands and low relief terrain with stable geologic formations. Any slope failures (past or future) would generally be rare and small in size.

Moderate (2) - Areas of moderate relief with some existing landslides or areas of steep terrain with stable geologic formations containing some landslides, but not a large number.

High (3) - Areas of moderate to high relief with unstable geologic formations or unfavorable geologic structure, with respect to orientation to natural slopes or future cuts. May have numerous or large landslides.



SAN LUIS OBISPO COUNTY
SANTA BARBARA COUNTY
SANTA MARIA RIVER
GUADALUPE
State Route 166
SANTA MARIA
COMPUTER ANALYSIS AREA BOUNDARY
Stowell Road
Santa Maria Valley R. R.
Black Road
Blosser Road
Betteravia Road
STUDY AREA BOUNDARY
BETTERAVIA
POINT SAL
Point Sal Beach State Park
Santa Maria Airport
State Route 1
State Route 135
U.S. HIGHWAY 101
Clark Avenue
ORCUTT
VANDENBERG AIR FORCE BASE
Southern Pacific R R
CASMALIA
N
SLOPE STABILITY, LANDSLIDES

Areas containing fairly severe landsliding and associated geologic formations are:

Foothills in the Summerland area (Rincon Formation)

Foothills of the South Coast - from Santa Barbara west to Gaviota Pass (Rincon and Monterey Formations)

Hope Ranch area - west of Lavigia Hill to Goleta (Rincon and Monterey Formations)

Sea cliffs along the coast from Santa Barbara to Gaviota, particularly those with out-of-slope dips (Monterey and Rincon Formations)

Solvang area south of the Santa Ynez River in the vicinity of, and east of, Alisal Ranch (Rincon, Sespe, Vaqueros, and Monterey Formations)

Areas east and northeast of Los Olivos near the Los Padres National Forest boundary (Paso Robles, Foxen and Franciscan Formations)

Lompoc area south of Santa Ynez River (Monterey and Sisquoc Formations)

Mountains south of Guadalupe and east of Point Sal (Point Sal, Foxen, Monterey, Lospe and Franciscan Formations)

EXPANSIVE SOILS

Expansive soils cause problems because they contain clay minerals that swell when the moisture content increases and shrink when the moisture decreases. Such soils are usually described as "adobe," and form ground cracks when they are allowed to dry out. The volume changes resulting from variable moisture conditions can cause movement and cracking of structures built on expansive soils. Soils beneath concrete floor slabs tend to increase in moisture content, thus causing heave. Soils under raised floors tend to dry out and shrink, causing settlement of the structure.

Expansive soils are very common in Southern California and many other areas in the world, and as a result, damage to structures is very widespread. Because some of the symptoms listed below are also typical of settlement or landsliding, a thorough investigation is sometimes required to determine the basic cause of distress.

Examples of Distress due to Expansive Soils

- Heaved and/or cracked floor slabs or exterior slabs
- Cracks in interior and exterior walls and ceilings

- Sticking doors and, less frequently, windows
- Slabs or porch steps pulled away from the building
- Ruptured utilities (rare)
- Tilted or "settled" posts or fences due to "creep" near slopes

The effects of expansive soils can be largely alleviated by proper design, construction and grading procedures without excessive cost. The distribution of expansive soils is generally erratic even in very local areas, and any future grading could change the site conditions and distribution of soil. For these reasons, expansive soils are considered to be less critical than many other geologic or soil problems in land use planning.

Expansive soils are often associated with those geologic units which also exhibit poor to marginal stability characteristics. In particular, expansive soils on or adjacent to slopes tend to cause creep which can be more difficult to control than the effects of expansive soils on flat ground. Geologic formations that are most often associated with expansive soil problems because of the soils derived from them are the Rincon, Monterey, and Paso Robles. The Rincon siltstone and claystone and residual or transported soils associated with this formation are considered to be some of the most expansive in Southern California. Structures located in them usually require special consideration in design (reinforcement), moisture control, and drainage to minimize the effects of expansive soil. The general location of these materials and knowledge of their expansive qualities is important in any proposed development.

Data regarding expansive soil characteristics and distribution in Santa Barbara County were obtained from the Soil Conservation Service. Soils with similar physical and chemical properties are grouped into the soil series. Expansive soil potential is one of the several soil characteristics used to differentiate and to classify the soil types. The primary test used by the Soil Conservation Service to determine the expansive characteristics of the soil is the coefficient of linear expansion (COLE). Based on this test, Atterberg Limit tests, and sieve analyses, the expansion for each soil type has been classified by the Soil Conservation Service as high, moderate or low. Generally, these classifications were employed in the computer model that produced the expansive soils maps. Where a particular soil series involved several layers with different characteristics, the expansion potential was rated by engineering judgment. Where soils were not classified by the Soil Conservation Service because of a lack of data or no testing (shown in white on the Expansive Soils Map), the soils were assumed to be moderately expansive with a high to low variation (26) in order to compute the Geologic Problems Index.

South Coast Study Area~East
Expansive Soils

Problem Rating

1. Low
2. Moderate
3. High

Note. Where no problem rating is shown, no Soil Conservation Service data on the characteristic were available, or no identified soil series were present.


LOS PADRES NATIONAL FOREST
STUDY AREA BOUNDARY
VENTURA COUNTY
SANTA BARBARA COUNTY
East Valley Road
Foothill Road
CARPINTERIA
Linden Ave
Casitas Pass Road
Rincon Rd
SUMMERLAND
SANTA BARBARA
N
0'
4,000'
EXPANSIVE SOILS

South Coast Study Area~West
Expansive Soils

<u>Problem Rating</u>

1. Low
2. Moderate
3. High

Note. Where no problem rating is shown, no Soil Conservation Service data on the characteristic were available, or no identified soil series were present.


State Route 154
COMPUTER ANALYSIS AREA BOUNDARY
U.S. HIGHWAY 101
Hollister Ave
NAPLES
ELLWOOD
Storke Road
ISLA VISTA
UCSB
AIRPORT
Ward Memorial Boulevard
GOLETA
SANTA BAR
U.S. HIGHWAY 101
GAVIOTA
EL CAPITAN
N
0'
4,000'
EXPANSIVE SOILS

Santa Ynez Valley Study Area
Expansive Soils

Problem Rating

1. Low
2. Moderate
3. High

Note. Where no problem rating is shown, no Soil Conservation Service data on the characteristic were available, or no identified soil series were present.

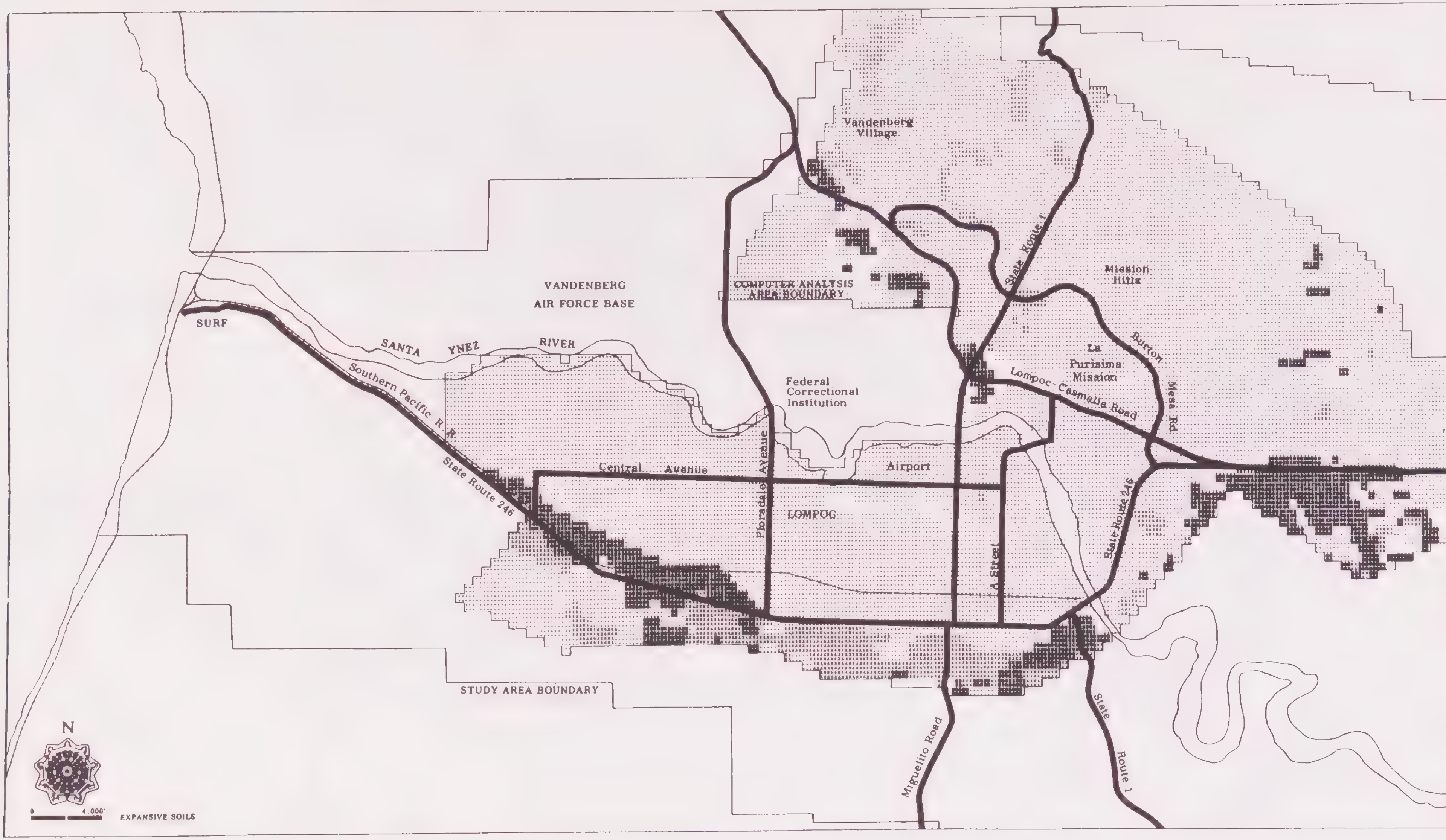
COMPUTER ANALYSIS AREA BOUNDARY
STUDY AREA BOUNDARY
HIGHWAY 101
LOS OLIVOS
BALLARD
BUELLTON
SOLVANG
SANTA YNEZ
SANTA YNEZ RIVER
Alisal Road
N
0'
4,000'
EXPANSIVE SOILS

Lompoc Study Area
Expansive Soils

Problem Rating

1. Low
2. Moderate
3. High

Note. Where no problem rating is shown, no Soil Conservation Service data on the characteristic were available, or no identified soil series were present.



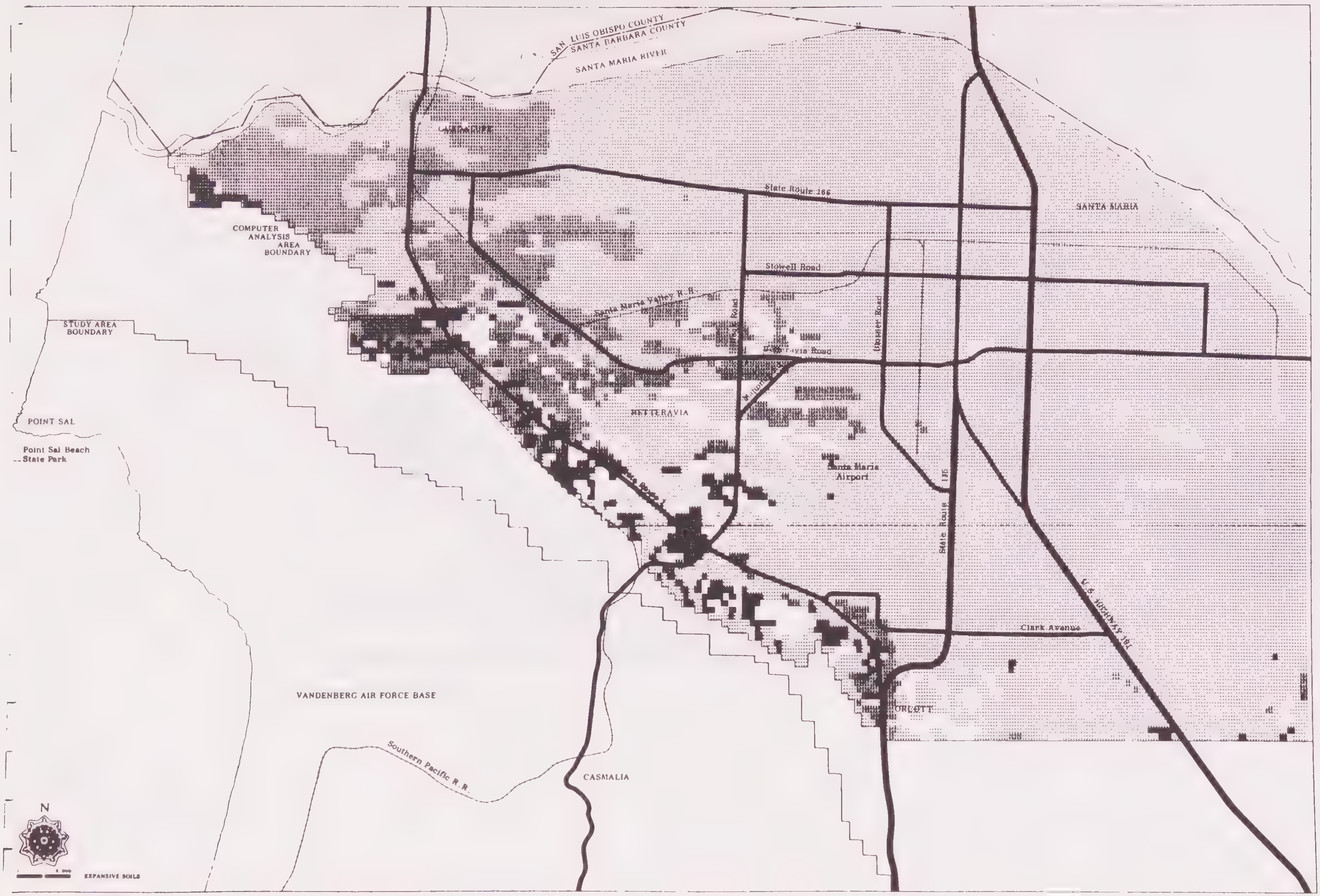
Vandenberg Village
VANDENBERG AIR FORCE BASE
COMPUTER ANALYSIS AREA BOUNDARY
SURF
SANTA YNEZ RIVER
Southern Pacific R.R.
State Route 246
Federal Correctional Institution
Mission Hills
La Purisima Mission
Burton Mesa Rd
Lompoc-Casmalia Road
State Route 1
Central Avenue
Floradale Avenue
Airport
LOMPOC
A Street
State Route 246
STUDY AREA BOUNDARY
Miguelito Road
State Route 1
N
0 4,000'
EXPANSIVE SOILS

Santa Maria-Orcutt Study Area
Expansive Soils

Problem Rating

1. Low
2. Moderate
3. High

Note. Where no problem rating is shown, no Soil Conservation Service data on the characteristic were available, or no identified soil series were present.



SAN LUIS OBISPO COUNTY
SANTA BARBARA COUNTY
SANTA MARIA RIVER
State Route 166
SANTA MARIA
COMPUTER
ANALYSIS
AREA
BOUNDARY
Stowell Road
Santa Maria Valley R.R.
STUDY AREA
BOUNDARY
BETTERAVIA
POINT SAL
Point Sal Beach
State Park
Santa Maria
Airport
State Route 135
U.S. HIGHWAY 101
Clark Avenue
ORCUTT
VANDENBERG AIR FORCE BASE
Southern Pacific R.R.
CASMALIA
N
EXPANSIVE SOILS

One Expansion Index test was performed by Moore & Taber on a typical sample of siltstone from the Rincon Formation. The test measures the expansion of a sample remolded to 50 percent of saturation when saturated under a load of 144 pounds per square foot. The sample had an index of 154 (15.4 percent expansion) which is considered very high. Other data indicate that higher values have been obtained in the Rincon Formation in different areas.

Expansive soils are fairly common in Santa Barbara County and are present in areas of current development such as the foothills of the South Coast (Summerland to Gaviota) and the Santa Ynez Valley (vicinity of Los Olivos, Ballard, Santa Ynez). For more detailed information on the location, distribution and degree of expansion of the various soil series, the Soil Conservation reports and maps for the North and South County should be referred to.

SOIL CREEP

Soil creep is the slow downslope movement of surficial soils. It involves clayey soils and is due - at least in large part - to the volume changes from cyclic wetting and drying. Although it can be a serious problem, it usually occurs on slopes or within a few feet of the top of them, so that most structures are protected by the required building setbacks. During periods of heavy and prolonged rains, the soils may become saturated and slump - a small shallow form of landslide involving only the upper few feet of surficial material.

Slope creep can be related, in a general way, to expansiveness and the steepness of slope. Like expansive soils, creep is one of the soil and geologic problems that can be rated quantitatively using expansion test results and measured slope data. Expansive soils data were taken from the Soil Conservation Service (SCS). The computer combined these two factors from previously encoded data in accordance with the table below to produce a creep model. The creep potential ratings of low, moderate, and high in the table correspond to numerical problem ratings of 1, 2 and 3 respectively as previously described.

TABLE OF CREEP POTENTIAL

	Soil Expansiveness (SCS)		
Slope	Non-Low	Moderate	High
0 - 10%	Low	Low	Moderate
11 - 20%	Low	Moderate	High
21 - 30%	Low	High	High
Over 30%	Moderate	High	High

South Coast Study Area ~East
Soil Creep Potential

Problem Rating

1. Low
2. Moderate
3. High

Note. Where no problem rating is shown, no Soil Conservation Service data on the characteristic were available, or no identified soil series were present.

SOIL CREEP POTENTIAL

South Coast Study Area ~West
Soil Creep Potential

Problem Rating

1. Low
2. Moderate
3. High

Note. Where no problem rating is shown, no Soil Conservation Service data on the characteristic were available, or no identified soil series were present.

State Route 154
COMPUTER ANALYSIS AREA BOUNDARY
NAPLES
Cathedral Oaks Road
Fairview Avenue
U.S. HIGHWAY 101
La Cumbre Road
Foothill Road
Hollister Ave
Los Palmas Drive
GOLETA
AIRPORT
Ward Memorial Boulevard
Storke Road
ISLA VISTA
ELLWOOD
UCSB
Cliff Drive
SANTA BAR
U.S. HIGHWAY 101
GAVIOTA
EL CAPITAN
N
SOIL CREEP POTENTIAL

Santa Ynez Valley Study Area
Soil Creep Potential

Problem Rating

1. Low
2. Moderate
3. High

Note. Where no problem rating is shown, no Soil Conservation Service data on the characteristic were available, or no identified soil series were present.

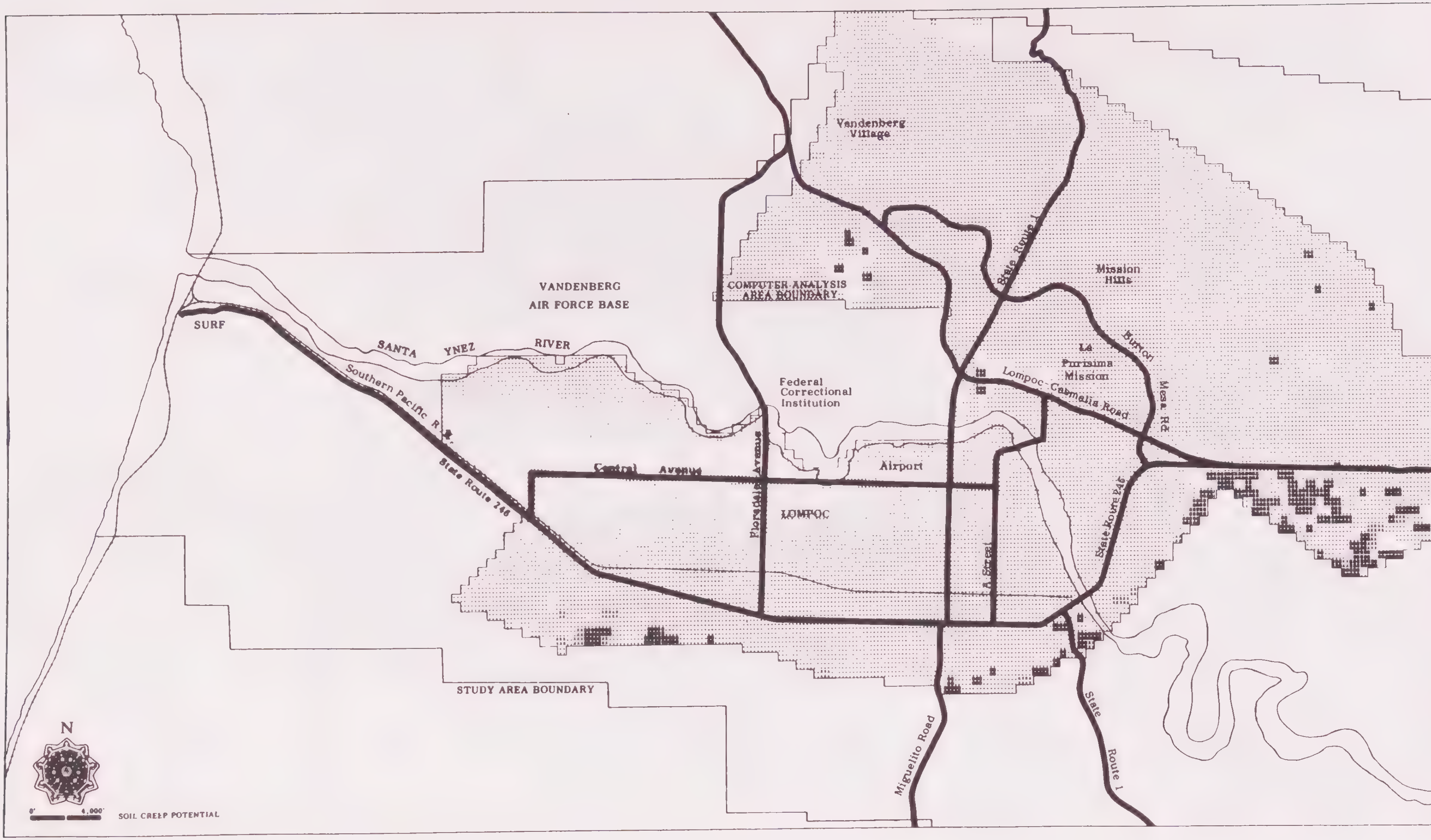

COMPUTER ANALYSIS AREA BOUNDARY
STUDY AREA BOUNDARY
HIGHWAY 101
LOS OLIVOS
State Route 154
BALLARD
Base Line Avenue
Road
Pinto
Refugio Road
SANTA YNEZ
Edison St.
State Route 246
BUELLTON
SOLVANG
Alamo
Airport
SANTA YNEZ RIVER
Alisal Road
N
0'
4,000'
SOIL CREEP POTENTIAL

Lompoc Study Area
Soil Creep Potential

Problem Rating

1. Low
2. Moderate
3. High

Note. Where no problem rating is shown, no Soil Conservation Service data on the characteristic were available, or no identified soil series were present.



SOIL CREEP POTENTIAL

Santa Maria-Orcutt Study Area
Soil Creep Potential

Problem Rating

1. Low
2. Moderate
3. High

Note. Where no problem rating is shown, no Soil Conservation Service data on the characteristic were available, or no identified soil series were present.

SAN LUIS OBISPO COUNTY
SANTA BARBARA COUNTY
SANTA MARIA RIVER
GUADALUPE
State Route 166
SANTA MARIA
COMPUTER ANALYSIS AREA BOUNDARY
Stowell Road
Santa Maria Valley R.R.
STUDY AREA BOUNDARY
Betteravia Road
POINT SAL
Point Sal Beach State Park
BETTERAVIA
Santa Maria Airport
State Route 1
State Route 135
U.S. HIGHWAY 101
Clark Avenue
VANDENBERG AIR FORCE BASE
ORCUTT
Southern Pacific R R
CASMALIA
N
SOIL CREEP POTENTIAL

The evaluation above means that the creep rating is low if the expansion is low, regardless of slope, but that creep may be moderate for highly expansive soils even though the slope does not exceed 10%. Where both the slope and expansion are high, obviously the creep potential is high.

Just as highly expansive soils can be related to particular geologic formations, similarly, areas susceptible to creep because of the presence of expansive soils can also be related to the same geologic formations. The Rincon and Monterey Formations form a black thick clay soil profile (adobe) which is subject to creep. Other formations that produce cohesive soils subject to creep are the Paso Robles, Sisquoc, Foxen, Anita, Franciscan, and, to some degree, siltstone members in the Vaqueros and Sespe.

Particularly good examples of creep and shallow slumps in the Rincon and Monterey Formations can be seen in the grass covered foothills along the South Coast, in the Alisal Ranch area south of Solvang, in the low hills south of Santa Ynez River, and on the north side of Highway 1 west of U. S. 101.

COMPRESSIBLE AND COLLAPSIBLE SOILS

Compressible and collapsible soils can cause settlement and damage to structures unless adequate precautions are taken.

Compressible Soils - Compressible soils are fine-grained cohesive soils of low strength, which consolidate and cause settlement when surcharged with fill or structure loads, particularly when saturated. Settlement of soil under load occurs slowly and may continue, although at a diminishing rate, for a number of years.

Compressible soils usually result from deposition in swampy, marshy environments, often in estuaries and sloughs. Since they are frequently associated with organic matter, and even include organic matter such as peat, they are commonly dark in color. Compressible soils are not particularly common in Santa Barbara County. However, several large areas of compressible soils exist along the South Coast in the old Goleta, Carpenteria, and Santa Barbara sloughs.

Collapsible Soils - Collapsible soils are low density, fine-grained, dominantly granular soils, usually with minute pores and voids. When these soils become saturated with water, they undergo a rearrangement of their grains, resulting in substantial and rapid settlement under relatively low loads. Therefore, such soils are extremely sensitive to an increase in moisture content caused either by a rise in the groundwater table or by increased surface water infiltration.

Collapsible soils are generally light in color, often reddish-brown, due to oxidation caused by free movement of air and moisture through the pores. Collapsible soils generally result from rapid deposition close to the source of the sediment where the material has not been reworked or had contact with enough moisture to form a compact soil.

To the best of our knowledge, the only notable case of a collapsing soil problem in Santa Barbara County is in the town of New Cuyama where corrective measures have been required to halt settlement of houses apparently supported on collapsible alluvium.

Preventive Measures - Areas with compressible or collapsible soils can be safely developed with one of several preventive measures, if the problem is recognized in the planning stage. Sites can be surcharged with fill or ponded with water and left to consolidate for some time before grading, the objectionable material can be removed to a depth where the additional load caused by development will not have any significant effect upon it, or the structure can be supported on piles that transmit the load to deeper, higher strength soil or bedrock. In some cases, structures can be supported by large reinforced grid or mat foundations which more evenly distribute the load and have enough strength so that any settlement will be uniform. The cost of these preventative measures will vary a great deal, depending on the severity of the problem. If settlement does occur, the problem can be alleviated by underpinning or compaction grouting, although these are rather expensive measures.

Severity Ratings - In assigning problem ratings for compressible/collapsible soils, it was assumed that moderate loads would be imposed on the soil, i.e., residential structures or light industrial buildings built upon a shallow compacted fill. Structures with heavier loads present their own group of problems and nearly always require special foundation considerations. A description of the criteria used in assigning problem ratings follows.

With a few exceptions, all bedrock was given a compressible/collapsible soils problem rating of low, generally with no variation (11) or variation to moderate (12) to allow for localized thick topsoil zones. A few of the older geologic formations which are highly fractured, subject to weathering, and may often develop thick soil profiles, were rated low with possible variation to high (14). The Rincon and Monterey Formations, which almost always develop a thick soil profile, were rated moderate to low (23), as was the older alluvial material. All landslides, including those mapped by photo reconnaissance, were rated moderate with possible variation from low to high (26) because of the generally disturbed and sometimes porous nature of landslide debris. Quaternary alluvium was rated low to high (14) except in canyons downstream from the

Santa Barbara County
Compressible - Collapsible Soils

	Problem Rating	Possible Variation from Assigned Rating
	1. Low	2. +1 (Moderate)
	1. Low	4. +2 (High)
	2. Moderate	3. -1 (Low)
	2. Moderate	6. ±1 (Low, High)


GUADALUPE
SANTA MARIA
Twitchell Reservoir
SANTA MARIA RIVER
State Route 166
CUYAMA RIVER
NEW CUYAMA
CUYAMA
SAN LUIS OBISPO COUNTY
KERN COUNTY
Stowell Rd
Betteravia Rd
BETTERAVIA
POINT SAL
GAREY
SISQUOC
ORCUTT
Clark Ave
CASMALIA
SISQUOC RIVER
State Route 33
VENTUCOPA
Zaca Lake
LOS PADRES NATIONAL FOREST
PURISIMA POINT
VANDENBERG AIR FORCE BASE
LOS ALAMOS
U.S. Highway 101
SURF
LOS OLIVOS
SANTA RITA
LOMPOC
BALLARD
BUELLTON
SOLVANG
SANTA YNEZ
VENTURA COUNTY
POINT ARGUELLO
SANTA YNEZ RIVER
LAS CRUCES
GAVIOTA
POINT CONCEPTION
MONTECITO
GOLETA
Hollister Ave
East Valley Rd
CARPINTERIA
SUMMERLAND
SANTA BARBARA
N
COMPRESSIBLE COLLAPSIBLE SOILS

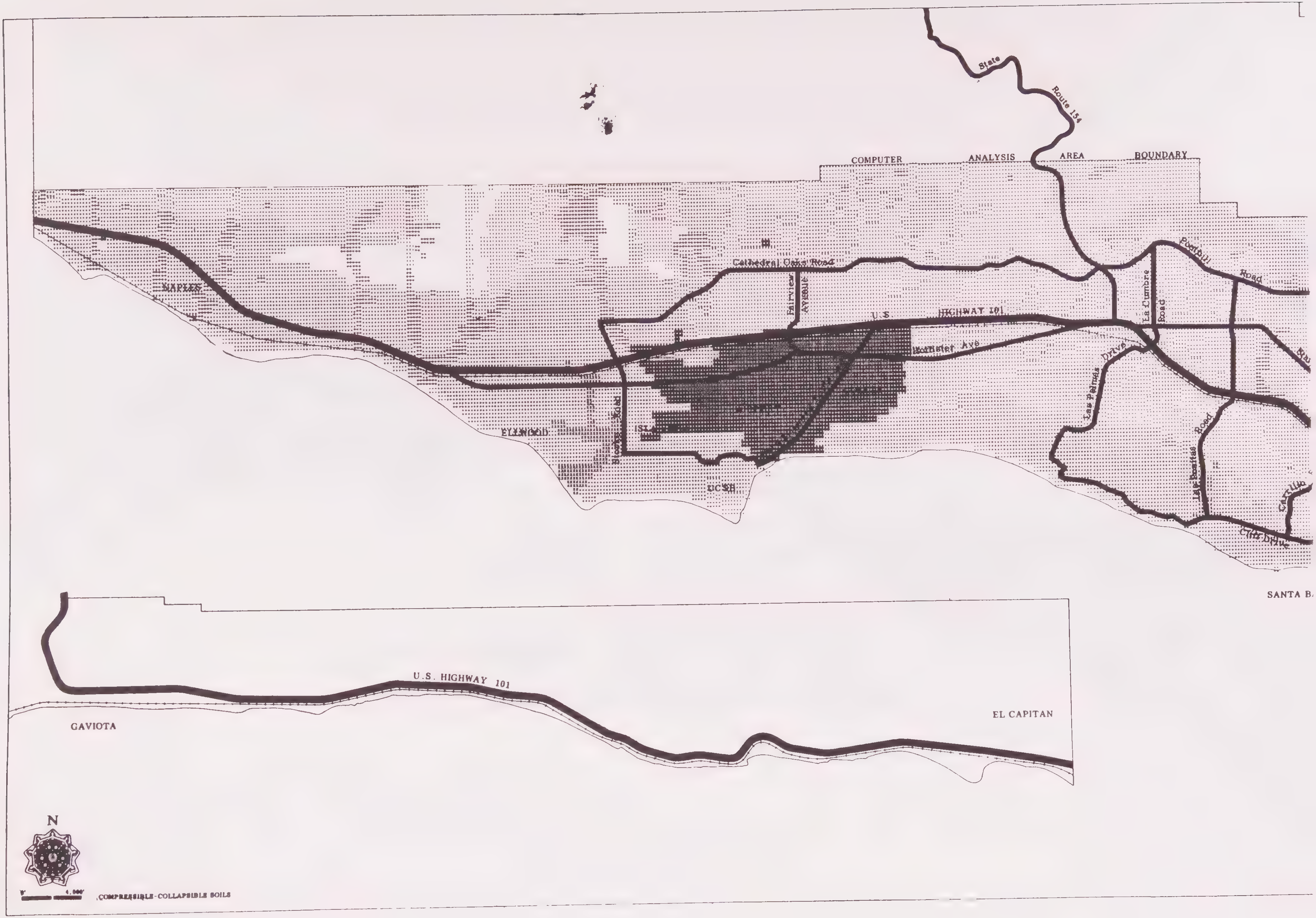
South Coast Study Area ~ East
Compressible - Collapsible Soils

	Problem Rating	Possible Variation from Assigned Rating
	1. Low	1. No Variation
	1. Low	2. +1 (Moderate)
	1. Low	4. +2 (High)
	2. Moderate	3. -1 (Low)
	2. Moderate	2. +1 (High)
	2. Moderate	6. ±1 (Low, High)
	3. High	3. -1 (Moderate)

COMPRESSIBLE-COLLAPSIBLE SOILS

South Coast Study Area ~West
Compressible - Collapsible Soils

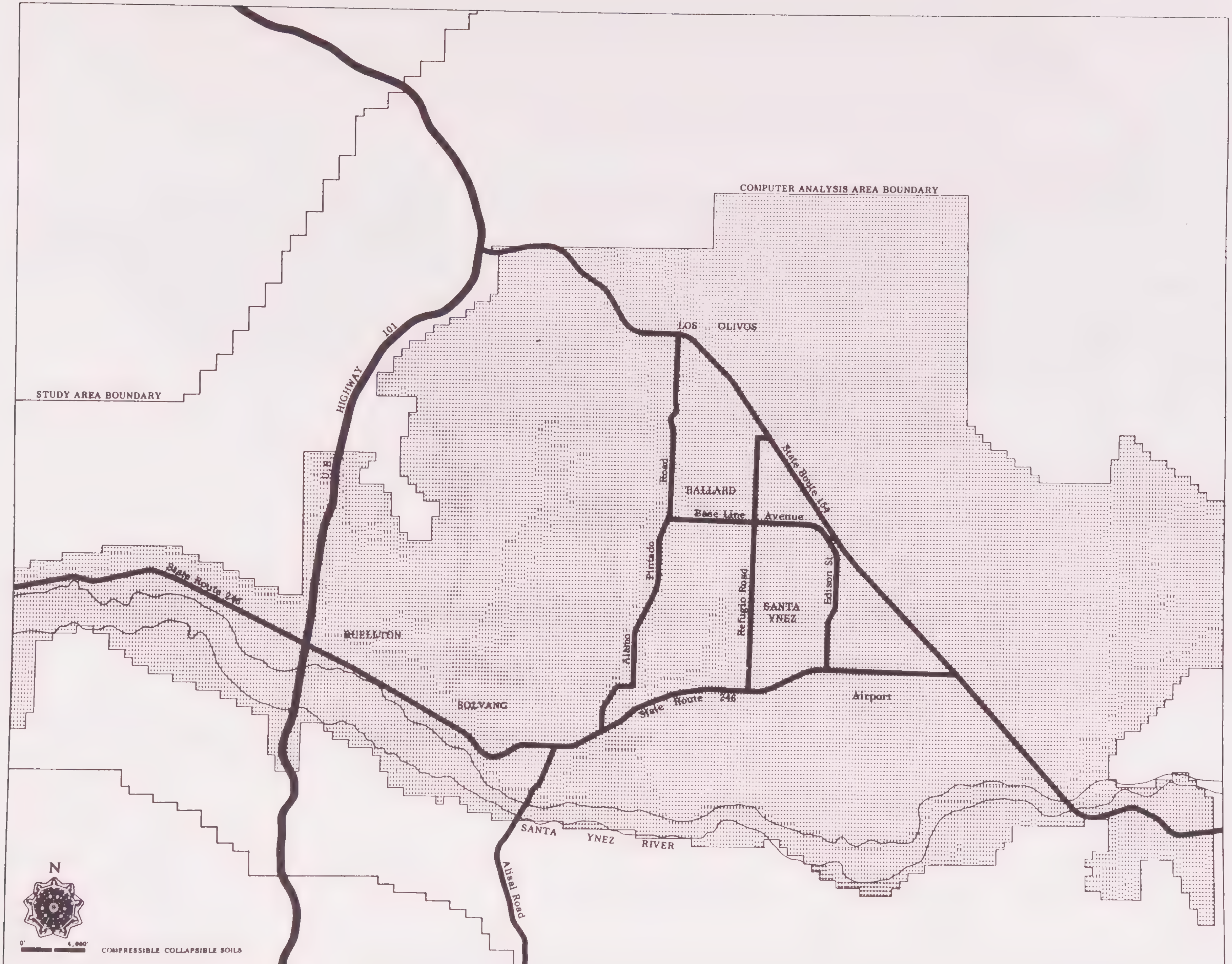
Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	3. -1 (Low)
2. Moderate	2. +1 (High)
2. Moderate	6. ±1 (Low, High)
3. High	3. -1 (Moderate)



State Route 154
COMPUTER ANALYSIS AREA BOUNDARY
Cathedral Oaks Road
Foothill Road
Fairview Avenue
La Cumbre Road
U.S. HIGHWAY 101
Hollister Ave
Las Palmas Drive
NAPLES
ELLWOOD
UCSB
SANTA B
U.S. HIGHWAY 101
GAVIOTA
EL CAPITAN
N
COMPRESSIBLE-COLLAPSIBLE SOILS

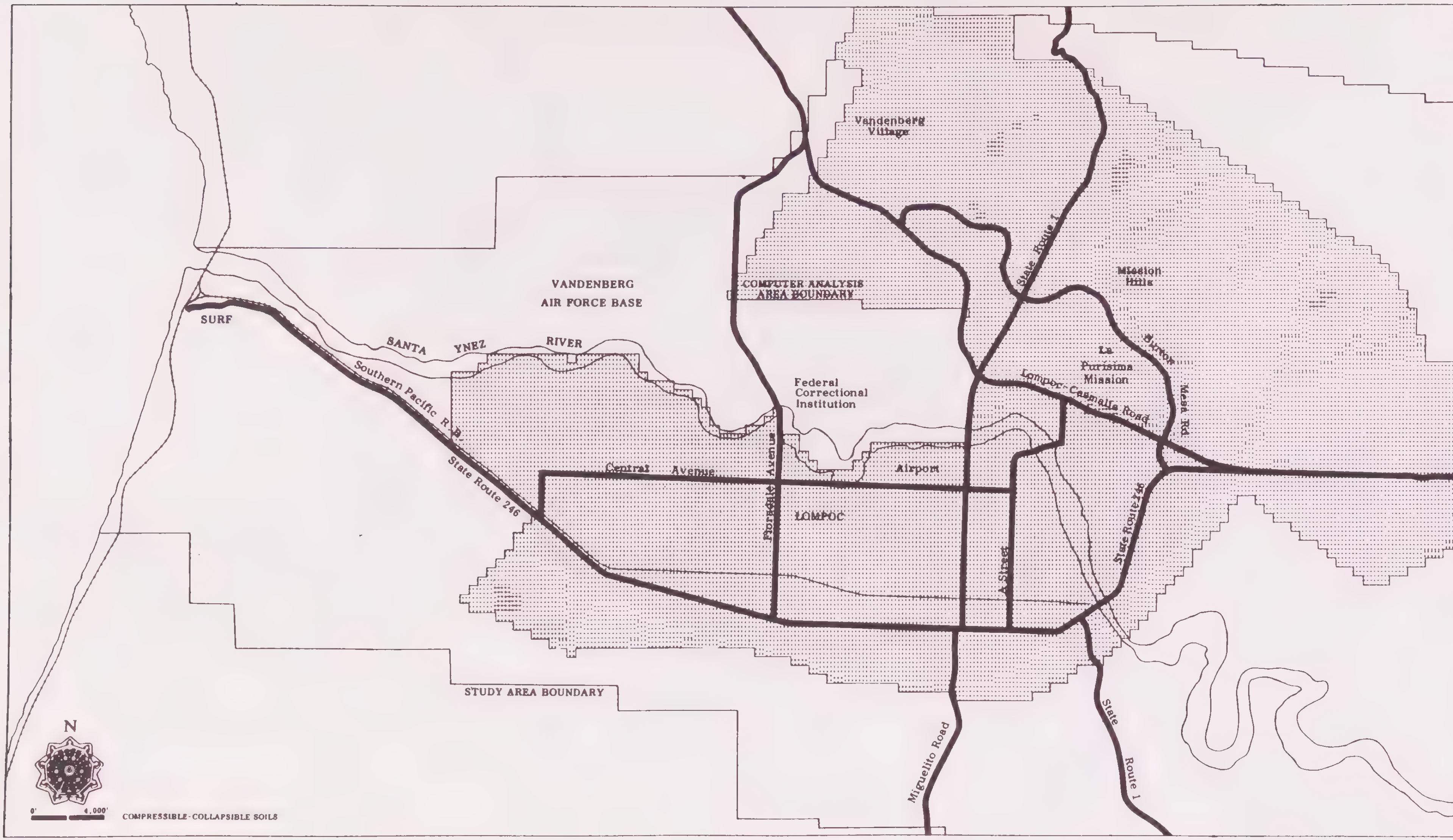
Santa Ynez Valley Study Area
Compressible - Collapsible Soils

Problem Rating	Possible Variation from Assigned Rating
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	3. -1 (Low)
2. Moderate	6. ±1 (Low, High)


COMPUTER ANALYSIS AREA BOUNDARY
STUDY AREA BOUNDARY
U.S. HIGHWAY 101
LOS OLIVOS
BALLARD
Base Line Avenue
State Route 154
Alamo Pintado Road
Refugio Road
Edison St.
SANTA YNEZ
State Route 246
BUELLTON
SOLVANG
Airport
SANTA YNEZ RIVER
Alisal Road
N
0'
COMPRESSIBLE COLLAPSIBLE SOILS

Lompoc Study Area
Compressible - Collapsible Soils

Problem Rating	Possible Variation from Assigned Rating
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	3. -1 (Low)
2. Moderate	6. ±1 (Low, High)



Vandenberg Village
VANDENBERG AIR FORCE BASE
COMPUTER ANALYSIS AREA BOUNDARY
Mission Hills
SURF
SANTA YNEZ RIVER
Southern Pacific R.R.
State Route 246
State Route 1
La Purisima Mission
Burton Mesa Rd.
Lompoc-Casmalia Road
Federal Correctional Institution
Central Avenue
Airport
Floradale Avenue
LOMPOC
A Street
STUDY AREA BOUNDARY
Miguelito Road
N
0'
4,000'
COMPRESSIBLE-COLLAPSIBLE SOILS

Santa Maria-Orcutt Study Area
Compressible-Collapsible Soils

Problem Rating	Possible Variation from Assigned Rating
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	3. -1 (Low)
2. Moderate	2. +1 (High)
2. Moderate	6. ±1 (Low, High)

SAN LUIS OBISPO COUNTY
SANTA BARBARA COUNTY
SANTA MARIA RIVER
GUADALUPE
State Route 166
SANTA MARIA
COMPUTER
ANALYSIS
AREA
BOUNDARY
Stowell Road
Santa Maria Valley R. R.
Black Road
Blosser Road
STUDY AREA
BOUNDARY
Betteravia Road
BETTERAVIA
POINT SAL
Point Sal Beach
State Park
Santa Maria
Airport
State Route 1
State Route 135
U.S. HIGHWAY 101
Clark Avenue
VANDENBERG AIR FORCE BASE
ORCUTT
Southern Pacific R. R.
CASMALIA
N
0'
COMPRESSIBLE-COLLAPSIBLE SOILS

Rincon Formation where sediment from that formation might cause a moderate problem with variation from low to high (26). Well-defined slough areas of known compressible soils and high groundwater were the only areas rated high, with variation to moderate (33). A boundary zone between the sloughs and the surrounding alluvium was rated 26 because of uncertainty as to the actual limits of the the compressible materials.

It should be emphasized that compressible soils were considered only for the underlying natural ground (soil, alluvium and bedrock). The rating did not take into account old fills and their potential settlement. Especially in the South Coast area, many old erosional gullies and canyons have been filled in the past, frequently with poorly or marginally compacted fill, with no record kept of this fact. Identification and rating of these isolated fills is not possible at the scale of mapping and was beyond the scope of the study, but thorough searches for them should be undertaken before any development project is begun. An example of this old fill is the filled lake, marshland and channels in the City of Santa Barbara in the vicinity of Laguna Street and the Junior High School, which has necessitated pile foundations for support of large buildings. Consideration should also be given to old filled oil well sumps, which can be found where drilling has been conducted in tne past. Study of old topographic maps or aerial photos can often help identify areas where uncontrolled fill has been placed.

Also of concern, and not considered in the ratings because it would require evaluation of specific grading plans, is settlement of deep fills. Present County requirements are fairly strict as far as inspection and compaction testing of fills are concerned. However, if fills are deep, even well compacted fills can consolidate to some degree and cause settlement if they become saturated. This occasionally causes detrimental differential settlement where structures are located across the contact between cut and fill or where the depth of fill under the structure varies substantially.

In summary, although settlement from compressible and collapsible soils can be prevented during development, it can cause significant property damage and can be expensive to prevent. The compressible/collapsible soils problem rating map should help identify areas where these soils could potentially be a problem. Assimilation of further, more detailed, information as more exploration is done in these areas could make the map an even more useful tool, and should be considered for future study.

HIGH GROUNDWATER

Near-surface groundwater, either as a main aquifer or in a perched condition, can be a geologic and engineering problem from the standpoint of liquefaction, settlement, slope stability, construction difficulties, and nuisance. Groundwater as it affects liquefaction potential is covered in a preceding section.

Based on groundwater information from U. S. Geological Survey and other publications, and from several personal communications, the various areas and rock units were rated with respect to groundwater problems. Groundwater levels with respect to the ground surface were used to rate the potential severity of the problem. For example, water in the upper eight feet might impose a problem to the construction of foundations, basements, utilities and roads. It would affect the bearing value of the soil for major structures, but probably would not affect residential structures. Generally speaking, water between 8 and 15 feet could pose a problem for larger structures or deeper excavations. Water below 15 feet would not constitute any significant problem except for the largest structures or those requiring deep excavations such as major storm drain or sewer projects.

Large or continuous groundwater bodies are not considered to be present in the bedrock formations older than uppermost Pliocene; these units generally are fairly well consolidated and contain water only in fractures or in some sandstone beds. Therefore, they have been given a groundwater problem rating of low with no variation (11).

The semi-consolidated and unconsolidated formations of upper Pliocene and Pleistocene age are generally quite granular and pervious, and are often water bearing (and producing) at depth, but surface exposures of these formations are usually above the zone of saturation. However, peculiar local conditions, such as an impervious cemented zone or clay seam overlying bedrock, could cause a perched groundwater problem.

Perched water conditions in the semi-consolidated formations of upper Pliocene and lower Pleistocene age are not widespread, but can occur; these formations have been given a groundwater problem rating of low with a possible variation to high (14). (The Plio-Pleistocene formations in this category include the Orcutt, Paso Robles, Careaga, Casitas, and Santa Barbara Formations.)

The upper Pleistocene terrace deposits and fanglomerates in Santa Barbara County are generally coarse grained, granular material. They may contain perched water zones, but are not considered common occurrences. They have been rated low with a possible variation

to moderate (12).

In the South Coast urban-study area, Older Alluvium and the Carpenteria Formation and coastal terrace deposits are also granular, but have a much higher incidence of groundwater problems, generally perched water, especially along the coastal bluffs and mesas. These formations have been given a rating of moderate with possible variation from low to high (26).

The dune sands in the Santa Maria Valley area have a moderate incidence of perched water conditions generated by impervious cemented "hard pan" zones within the dunes - generally ferric oxide layers. Therefore, all dune sands have been rated the same as the Older Alluvium, (26).

In the two cases above, the groundwater problem rating of 26 has been applied to formations in areas which have known groundwater problems. In the case of large landslide masses, the general character of slide material - disturbed, fractured material usually underlain by a relatively impervious shear zone - lends itself to possible perched water conditions, and so all landslides which were mapped by the original authors of the sources for our geologic maps (but not the slides identified by air photo-reconnaissance) have also been given a moderate-low to high rating (26).

In the formations discussed above, perched water is generally the only problem encountered - the actual water table is generally deep enough so as not to pose a problem. In the areas underlain by Quaternary alluvium, however, it is possible to have the actual water table at or near the surface, or to have confined water whose piezometric surface is at, near, or even above the level of the ground surface. It was beyond the scope of this study to gather the data necessary to rate these confined water areas within the alluvium, and so all alluvial areas have been rated in the same manner, as follows. A copy was obtained of the spring, 1970 to spring, 1973 well data for wells in the U.S.G.S. monitoring program in Santa Barbara and Southern San Luis Obispo Counties (U.S.G.S. open file report/Lamb and Mermod, 1973). This compilation consists of level data for approximately 500 wells, with anywhere from a single reading to several dozen level readings for each well during that three year period.

Three depth classifications were established: 0-8 feet, 8-15 feet, and deeper than 15 feet. The highest single level reading during the three-year period, (with some judgment applied) was used to classify all wells located within or adjacent to the four urban study areas. The well locations were plotted (nearly all were in alluvial areas), and zones of various depth to water table were drawn.

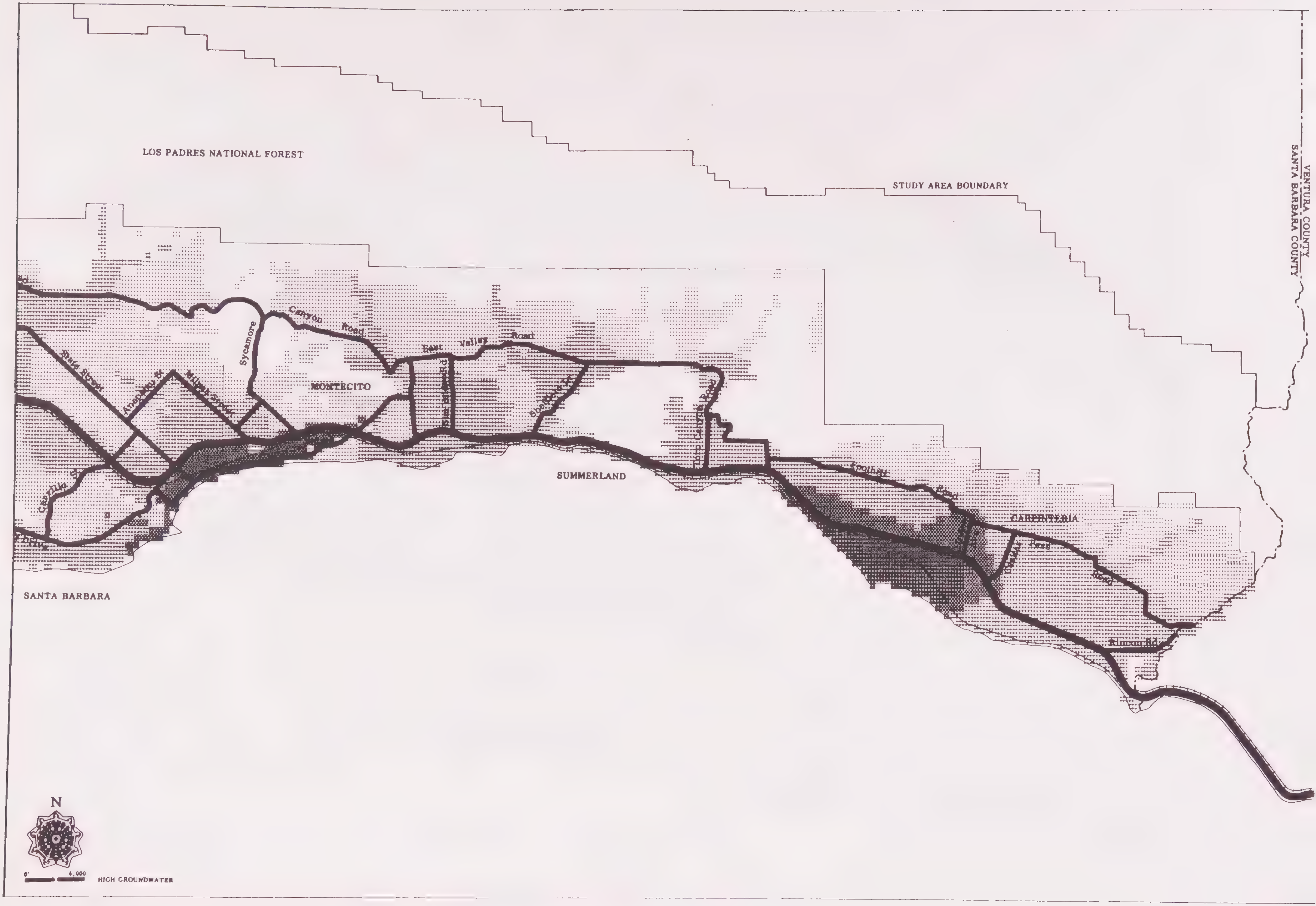
Santa Barbara County
High Groundwater

Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	4. +2 (High)
2. Moderate	6. ±1 (Low, High)
3. High	5. -2 (Low)
3. High	3. -1 (Moderate)
3. High	1. No Variation

GUADALUPE
SANTA MARIA
SANTA MARIA RIVER
Twitchell Reservoir
State Route 166
CUYAMA RIVER
CUYAMA
SAN LUIS OBISPO COUNTY
KERN COUNTY
POINT SAL
ORCUTT
GAREY
SISQUOC
CASMALIA
BISQUOC RIVER
VENTURA COUNTY
Zaca Lake
LOS PADRES NATIONAL FOREST
PURISIMA POINT
VANDENBERG AIR FORCE BASE
Lompoc Casmalia Road
LOS ALAMOS
SURF
SANTA RITA
LOS OLIVOS
LOMPOC
BALLARD
BUELLTON
SANTA YNEZ
SOLVANG
State Route 1
POINT ARGUELLO
State Route 154
SANTA YNEZ RIVER
LAS CRUCES
Highway 101
GAVIOTA
POINT CONCEPTION
MONTECITO
CARPINTERIA
SUMMERLAND
SANTA BARBARA
N
HIGH GROUNDWATER

South Coast Study Area -East
High Groundwater

Problem Rating	Possible Variation from Assigned Value
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	6. ±1 (Low, High)
3. High	5. -2 (Low)
3. High	3. -1 (Moderate)
3. High	1. No Variation



LOS PADRES NATIONAL FOREST
STUDY AREA BOUNDARY
VENTURA COUNTY
SANTA BARBARA COUNTY
Sycamore
Canyon Road
East Valley Road
MONTECITO
SUMMERLAND
CARPINTERIA
Foothill Road
Rincon Rd.
SANTA BARBARA
N
0'
4,000
HIGH GROUNDWATER

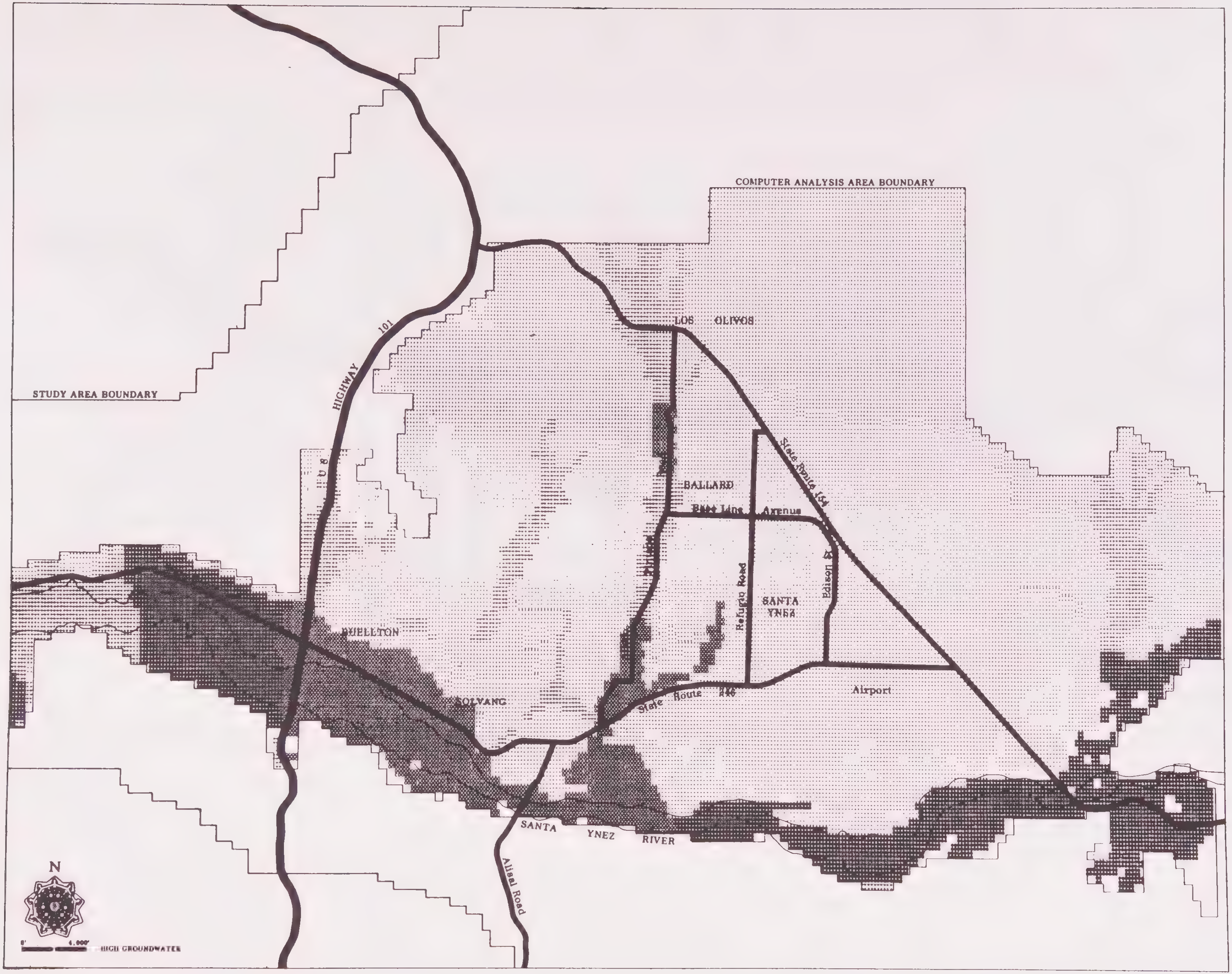
South Coast Study Area ~ West
High Groundwater

Problem Rating	Possible Variation from Assigned Value
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	6. ±1 (Low, High)
3. High	5. -2 (Low)
3. High	3. -1 (Moderate)
3. High	1. No Variation

State Route 154
COMPUTER ANALYSIS AREA BOUNDARY
NAPLES
Cathedral Oaks Road
U.S. HIGHWAY 101
Hollister Ave
GOLETA
ELLWOOD
Foothill Road
La Cumbre Road
Las Palmas Drive
Las Positas Road
Cliff Drive
SANTA BA
U.S. HIGHWAY 101
GAVIOTA
EL CAPITAN
N
HIGH GROUNDWATER

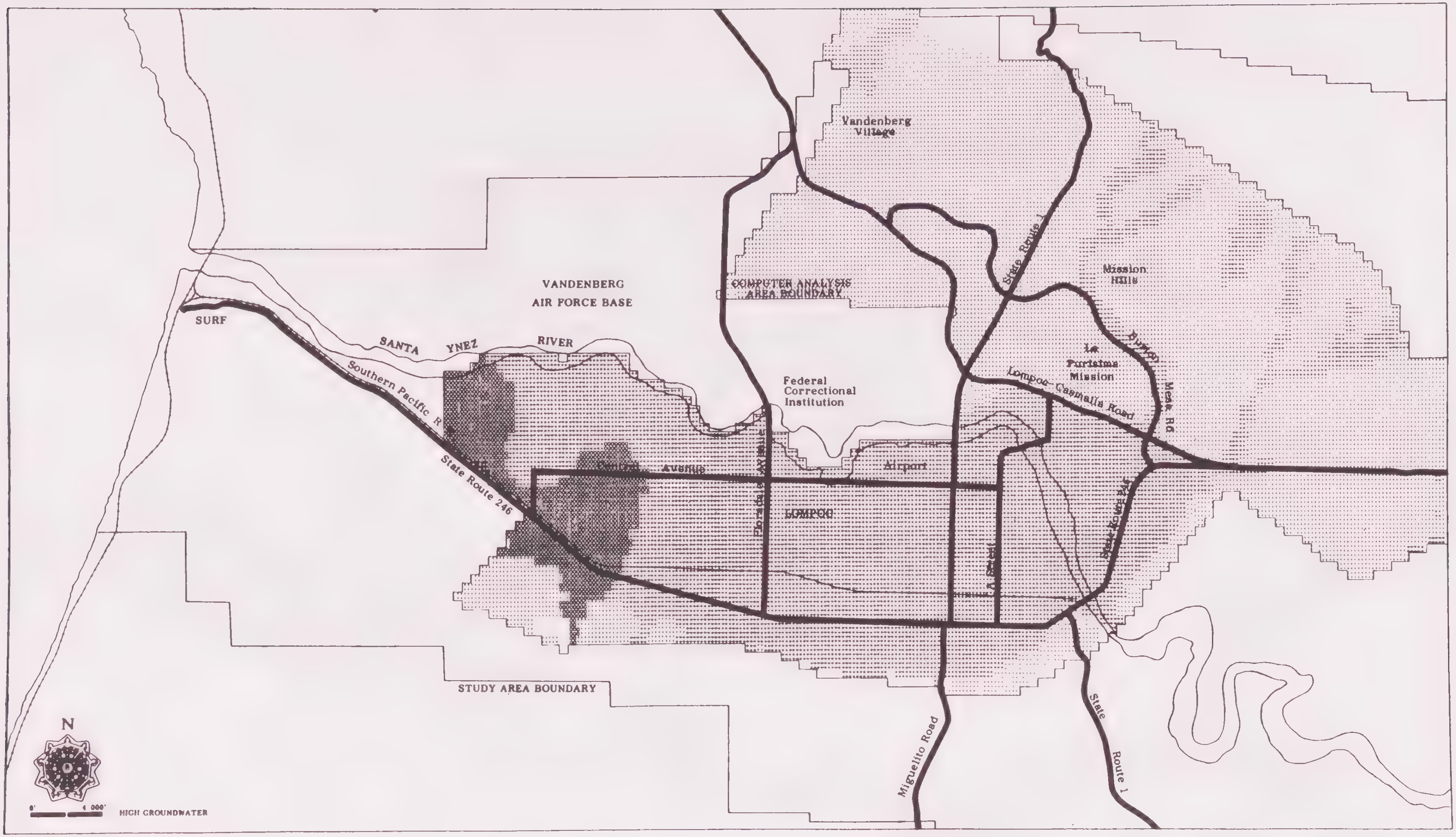
Santa Ynez Valley Study Area
High Groundwater

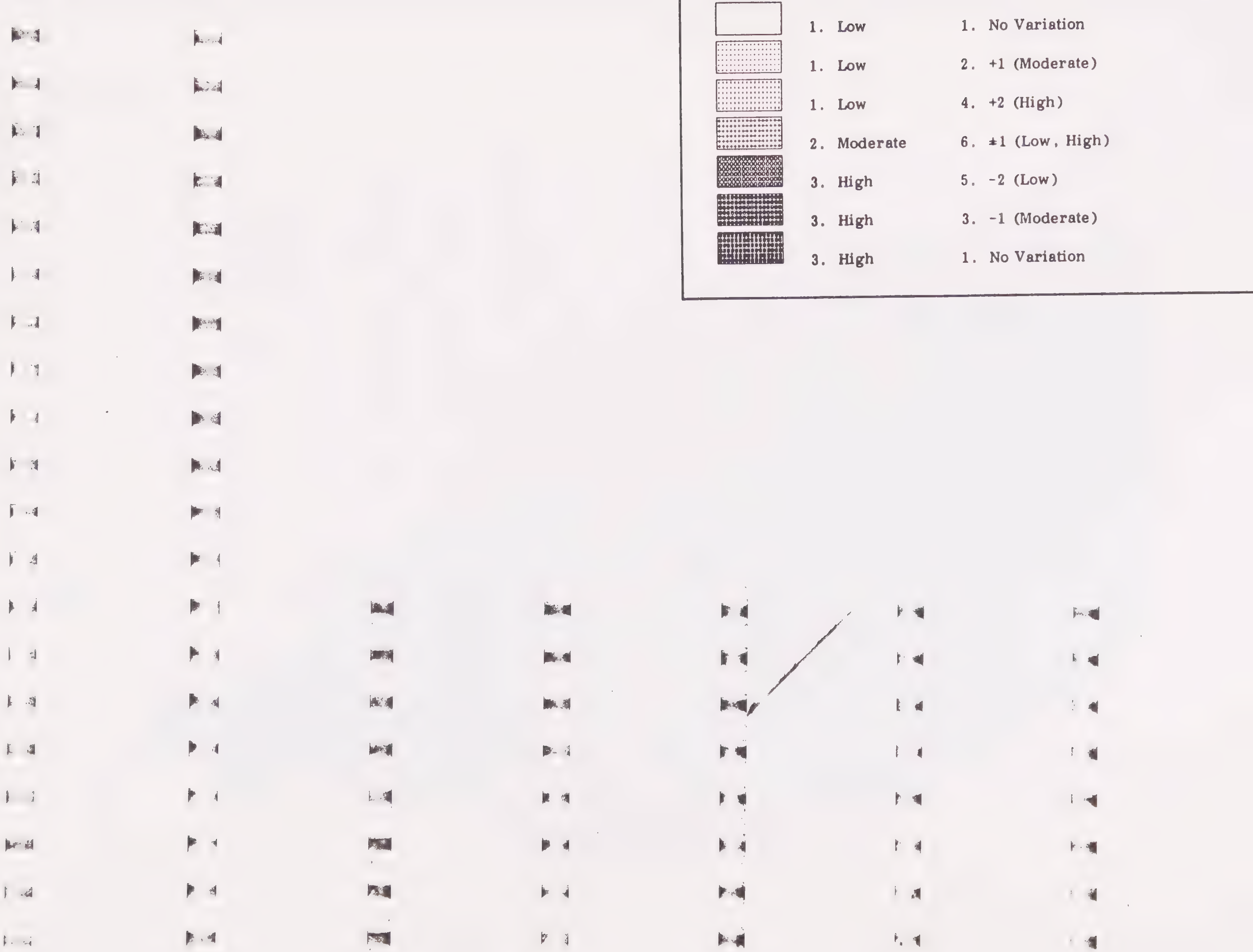
Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	6. ±1 (Low, High)
3. High	5. -2 (Low)
3. High	3. -1 (Moderate)


COMPUTER ANALYSIS AREA BOUNDARY
STUDY AREA BOUNDARY
U S HIGHWAY 101
LOS OLIVOS
BALLARD
State Route 154
Refugio Road
SANTA YNEZ
BUELLTON
SOLVANG
State Route 246
Airport
SANTA YNEZ RIVER
Alisal Road
N
0'
HIGH GROUNDWATER

Lompoc Study Area
High Groundwater

Problem Rating	Possible Variation from Assigned Rating
1. Low	1. No Variation
1. Low	2. +1 (Moderate)
1. Low	4. +2 (High)
2. Moderate	6. ±1 (Low, High)
3. High	5. -2 (Low)
3. High	3. -1 (Moderate)


Vandenberg Village
VANDENBERG AIR FORCE BASE
COMPUTER ANALYSIS AREA BOUNDARY
SURF
SANTA YNEZ RIVER
Southern Pacific R R
State Route 246
Federal Correctional Institution
State Route 1
Mission Hills
La Purisima Mission
Lompoc-Casmalia Road
Mesa Rd
Airport
LOMPOC
STUDY AREA BOUNDARY
Miguelito Road
State Route 1
N
HIGH GROUNDWATER


1. Low 1. No Variation
1. Low 2. +1 (Moderate)
1. Low 4. +2 (High)
2. Moderate 6. ±1 (Low, High)
3. High 5. -2 (Low)
3. High 3. -1 (Moderate)
3. High 1. No Variation


SAN LUIS OBISPO COUNTY
SANTA BARBARA COUNTY
SANTA MARIA RIVER
COMPUTER ANALYSIS AREA BOUNDARY
STUDY AREA BOUNDARY
SANTA MARIA
Betteravia Road
BETTERAVIA
POINT SAL
Point Sal Beach State Park
ORCUTT
VANDENBERG AIR FORCE BASE
Southern Pacific R.R.
CASMALIA
N
HIGH GROUNDWATER

Water 0 to 8 feet deep was given a groundwater problem rating of high, with possible variation to moderate (33); water 8 to 15 feet deep was rated high with possible variation to low (35); and water deeper than 15 feet was rated moderate, low to high (26). No-data areas adjacent to areas rated 33 or 35 were given the same rating as the adjacent areas; all other no-data areas were rated 26. Obvious marsh areas shown on the U.S.G.S. topographic maps were given a rating of high-no variation (31). It should be re-emphasized in conclusion that the ratings according to depth to water surface were given only in areas underlain by Quaternary alluvium, where adequate well data were available.

In overview, it might be asked why areas with no present perched water problems have been rated the same as areas with known problems. As in the rest of this study, we have attempted to correlate the various geologic problems with rock formations. Thus, it is assumed that since some areas underlain by Older Alluvium have perched water problems, then the other areas underlain by Older Alluvium, although presently undeveloped and with no groundwater problem, also have the possibility for a perched condition when development brings new input of water (from landscape water, sewage disposal systems, altered runoff pattern, etc.). Thus, all the Older Alluvium was rated 26, and similarly the older formations were generally given a single rating for all mapped areas of that formation.

It should also be recognized that where we have rated on the basis of depth to groundwater in the alluvial areas, the water level can vary dramatically due to differing climatic conditions, changes in pumping and recharge programs, altering of runoff by development, and other factors. Therefore, ratings based on depth of water should be revised periodically to conform with new input data. The U.S.G.S. is currently in the process of computer-compiling all historically available well data on all wells (even though some wells have been destroyed or abandoned) in Santa Barbara County. When these data are available and with sufficient time allotted, they could be used to great benefit in better defining areas with potential high groundwater problems.

Areas of known high groundwater include:

- Goleta Slough
- Carpinteria Slough
- More Mesa - Hope Ranch (perched water)
- Vandenberg Village (perched water)
- Santa Maria Airport Area (perched water)
- Lowlands west of Guadalupe
- Los Alamos Area

EROSION

Erosion as discussed in this section is considered to be the result of limited water flow and thus is distinguished from major water flows associated with flood hazard, which is not within the scope of this study.

Susceptibility to erosion was not given great emphasis in the study - or included in the Geologic Problem Index because it is not very critical from a planning viewpoint; it can usually be controlled with good design at low to moderate cost. Slope planting, proper watering and maintenance, and control of drainage will substantially minimize the effects of erosion.

Erosion is a function of the soil or rock characteristics, slope gradient, and water flow, which can vary greatly in short distances. Therefore, erosion is not adaptable to mapping or rating at the generalized scales of the study. Most soils in the County are susceptible to erosion to some degree but the following geologic formations because of their basic granular characteristics - in part or whole - are considered most subject to erosion and where encountered should be evaluated for this problem: Fanglomerate, Terrace and Older Alluvium deposits, Casitas, Santa Barbara, Pico, Paso Robles, Careaga and Orcutt Formations. Recent and old sand dunes not anchored by vegetation are subject to wind erosion and considerable movement.

SHORELINE REGRESSION

An erosion-related problem of more significance, but one also impractical to map on a scale of 1" = 2000' because it involves such a narrow zone, is erosion of the sea cliffs along the coast. Locally this can be quite significant, but involve such small (although quite valuable) areas that they are more appropriately the concern of Building and Safety Department review of specific projects rather than evaluation in overall planning. However, for completeness and because it can be a serious problem, shoreline regression is discussed. Cliff retreat as it relates to mass earth movement (landslides) has been included and rated on the Slope Stability maps.

Processes of Cliff Retreat

The chief processes involved in sea cliff retreat due to marine and non-marine causes are described below:

1. Undercutting. Waves act somewhat as a horizontal saw, abrading the cliff base by direct impact of water, and picking up and hurling broken rocks at the cliff base. Adversely inclined strata are undercut and left unsupported. Air compressed in

the rock joints, exerts a pressure on the joint faces. As undercutting progresses, unsupported slabs above break away and add their debris to abrading materials.

2. Failure along vertical or steep joints. Where joint cracks are vertical or nearly vertical, water pressure and tree roots may gradually wedge slabs away from the cliff. This is aided, of course, by undercutting.

3. Oversteepening of cliff materials. Even where undercutting does not occur, waves may remove materials supporting the base of a cliff and produce instability because the resultant slopes are steeper than the materials can sustain.

4. Rainwash and surface weathering. Because of the steep gradients, direct wash on cliff faces may produce gullies in soft materials. Cliffs cut in soft, sandy, or gravelly beds with little interstitial cement are commonly deeply gullied or fluted by rain running down the cliff face. The Pico and Casitas Formations, and Older Alluvium and Fanglomerate are especially vulnerable. All exposed materials are subject to slow weathering and a consequent loss of strength.

5. Spring sapping. In some places, particularly where development has resulted in the planting of lawns, landscaping, and installation of private sewage disposal systems, wastewater may find its way to cliff faces where springs and seeps will occur. The continual emergence of water weakens and removes soft sedimentary materials, causing sapping near the emerging water. This process is contributing to the rapid rate of cliff retreat at More Mesa near Santa Barbara, where a rate of ten inches per year has been measured.

6. Piping. This phenomenon occurs in weakly consolidated rocks possessing systems of vertical and horizontal cracks or joints. Water enters these small channels from above, eventually emerging on the cliff face below. Owing to the ease of erosion, the channels are widened until large blocks of the cliff face may be rendered quite unstable.

7. Air slaking and weathering. Cliff faces are exposed to salt spray which can accelerate the process of weathering and deterioration of the slope.

Irrespective of rock type, all sea cliffs are subject to erosion by marine and non-marine processes as noted above. Unfortunately, most of the coastal cliffs in Santa Barbara County are cut into comparatively incompetent rocks which are subject to relatively rapid erosion and mass movement in response to wave action. The

Monterey and Sisquoc Formations comprise the larger portion of the Santa Barbara County coastal cliffs. These formations readily yield to erosion, slumping, landsliding, and similar processes chiefly for the following reasons:

1. They are composed of thin-bedded sedimentary rocks, which frequently dip seaward. As waves attack the cliffs, the beds are undercut and left unsupported so that movement - slow or rapid - can occur along the bedding planes which represent surfaces of weakness.

2. Volcanic ash beds occur in both formations. These are soft and incoherent materials with little shear strength. Where such beds are adversely inclined, overlying materials may move downslope. Moreover, where these soft beds are exposed to direct wave attack, they allow relatively rapid excavation of narrow channel-like caves, which as they enlarge, weaken the overlying cliffs.

3. Both formations are frequently tightly folded and crumpled, with resulting joint systems which extend near to the ground surface. The thin, brittle rocks respond by extensive fracturing, which may reduce large masses of rock to little more than unstable piles of rock rubble at the toe of the cliff.

4. The abundance of bedding planes and joint cracks allows water to enter the formations at many places, further reducing shearing strength.

Rates of Cliff Retreat

The only portion of the County's coast where a systematic attempt has been made to assess rates of cliff retreat is near Goleta, between Santa Barbara and Coal Oil Point. Measurements have been made, showing that the coastal cliffs are retreating from three to ten inches a year, on the average. Six inches would be a likely average for this part of the South Coast, and it is likely that retreat of this magnitude can be expected from Rincon Point to Point Conception, although this has not been documented. These figures are averages based on observed rates over ten to thirty-five year periods and do not mean, necessarily, that six inches of cliff will be lost annually. Cliff retreat is a spasmodic phenomenon and occurs more by slab or large block failure at one time rather than by grain by grain loss. Recent examples of this type of large block or slab failure of four feet or more can be seen in the cliffs along Isla Vista.

Construction of dams and reduction or diversion of flood discharges in streams can be expected to have long-term unfavorable effects on beaches as they already have in the Los Angeles Basin area. A well-developed beach is not only an important resource for its own sake but is also a highly efficient absorber of wave energy, thus providing substantial protection for shoreline cliffs.

SUBSIDENCE

The meaning of subsidence as used herein refers to deep-seated settlement due to the withdrawal of fluids (water, oil, or natural gas) and should be differentiated from settlement caused by consolidation of compressible or collapsible soils, discussed previously. Subsidence tends to cover broad areas, and the magnitude of movement can be quite large. The best examples are approximately 29 feet of subsidence which has occurred in the San Pedro - Terminal Island area associated with oil field operations and approximately 25 feet of subsidence which has been attributed to natural gas production in Italy and Japan. Subsidence usually occurs over such a wide area that it tends to be uniform and non-differential within areas covered by a single structure. However, long continuous structures (aqueducts, roads, utility lines) may be subject to damage. Damage, related to subsidence, can also occur to oil, gas or water wells due to horizontal movement at depth, and in coastal lowlands an overall lowering of the ground elevation can produce flooding.

It should be noted in spite of the major movements cited above - that fluid withdrawal frequently does not result in significant subsidence.

The surest way to prevent subsidence is to halt fluid withdrawal in areas where it could create problems, or to maintain or restore pressure by injection of a different fluid. Groundwater recharge programs to replenish underground water supply have been successfully used to offset subsidence associated with fresh-water withdrawal in the Los Angeles Basin. Closely-controlled fluid injection into depleted oil or gas producing zones has had similar success in reducing subsidence.

Despite inquiries to responsible agencies, no evidence of significant subsidence or problems related to subsidence in Santa Barbara County were uncovered. However, to our knowledge, no precise level lines or surveys have been measured in oil, gas or water producing areas in Santa Barbara County. Subsidence could be occurring in these areas, but if so, it is not significant since no problems have been reported. Establishment of a grid base and precise level surveys would be needed to determine subsidence.

Sand Movement Along Coast

There is little disagreement that beach sand is moved by longshore current and beach drifting south from the mouth of the Santa Maria River (and farther north as well) to at least Point Pedernales or Point Arguello. Both the trend of the shoreline and the prevailing direction of the wind and wave approach indicate a net southerly movement on most days. Sand movement around the rocky Point Arguello headland, across the Jalama bight, and around Point Conception is strongly suspected, but not yet well-documented. Most of the published studies are based on limited data or have yielded equivocal results. A study in progress may provide good information on the magnitude of sand bypassing these headlands.

There seems little question that, eastward from Point Conception, beach sand moves easterly more than 300 days out of the year, under the influence of waves striking the shoreline obliquely as they move down the Santa Barbara Channel from the west.

Studies have shown that, in the vicinity of Santa Barbara, the volume of daily sand transport past a given point ranges from a low of about 300 cubic yards per day during the summer (quiet wave conditions) to highs of more than 4500 cubic yards per day during stormy periods in winter. The average has been found to be about 700 to 750 cubic yards daily. This persistent eastward-flowing stream of sand on the beach must be taken into account whenever beach structures or harbors are contemplated. Forty-five years of experience at Santa Barbara and Montecito have shown clearly the effects of downshore sand movement.

Although present data are too limited for adequate documentation, it is likely that the volume of sand moved along the beach increases from Point Conception to Rincon Point. In Ventura County, with similar wave conditions but with a much larger supply of river sand derived from the Ventura and Santa Clara drainages, the volumes of sand movement are at least double those of Santa Barbara. If one assumes that something less than 700 cubic yards of sand per day moves around the Point Conception headland, as seems probable, the amount of sand moved along the South Coast should rise toward the east as the contributions of more and more streams are added to the total.

Stream sand is the chief source of beach sand and in turn of coastal dune sand, where such dunes are present. For this reason, any activity or construction that reduces the amount of sand delivered by streams to the beaches can be expected to be reflected ultimately in a diminished beach width. It is already well-known that the incidence of several dry years and minor stream flows in succeeding years is followed by a narrowing of the beaches.

V. Conclusions and Recommendations

SUMMARY OF GEOLOGIC PROBLEMS

Geologic Problem Index

In some areas geologic, seismic, and soil conditions are major factors affecting land use and should - along with other pertinent factors - be taken into account. In order to simplify the planning process, the results of all problems - excluding ground displacement from fault offset - have been combined into a single number called a Geologic Problem Index or GPI. The GPI for a given area is obtained by multiplying each problem by a weighting factor that considers the seriousness of the problem, the difficulty of alleviating it, and - to some extent - the frequency of occurrence.

The GPI's theoretically range from a low of 100 for land with essentially no problems to a maximum of 300 for land with serious problems of all types. However, in actual application, the numbers range in Santa Barbara County from a minimum of 100 to a maximum of 236. Only a small part of the County, in the Santa Maria area, actually has a theorectically low GPI of 100. The maximum value of 300 was not possible because some of the problems evaluated are restricted to flatland areas (liquefaction, for example) and some to hilly areas (landslides).

Computer Classification - Severity Categories

To further aid the planning process, the range of GPI's was then divided into categories I through V, low, low-moderate, moderate, moderate-severe, and severe respectively.

Computer analysis areas within the study areas were divided into approximately five-acre grid cells, and the GPI calculated for each cell. The GPI was then assigned to the appropriate severity category (I through V) and displayed on a computer-produced map. The same procedure was followed for the entire County, utilizing grid cells approximately ninety acres in size. Computer analysis areas for the four study areas were defined by excluding the steeper hillsides and more remote undeveloped areas. The only areas excluded on the County-wide computer map were the National Forest lands and parts of Vandenberg Air Force Base.

Thus, the computer maps reflect a summation of the ratings delineated on the eight Geologic Problems Maps, with one exception. The Seismic - Tectonic Maps have been drawn and problem ratings assigned based on a possible extension of the Big Pine fault. However, the computer maps do not reflect the GPI arising from

ground shaking caused by this fault. If further investigation should confirm the existence of this fault, the GPI's should be recalculated. The effects of confirming the fault extension would be to raise - and thus eliminate - all areas with a ground shaking problem rating of 1 (low) to 2 (moderate), and to change some areas with a 2 (moderate) rating to a 3 (high) rating. Changes would occur on all but the South Coast GPI map, and would mean that a small percentage of the cells would have a GPI increase of eighteen points. Also, since there would be no areas with a ground shaking problem rating of 1 (low), the lowest possible GPI would be 118 rather than 100, as is now the case for an area with all problems rated 1 (low).

The five severity categories into which the cells are divided, based on GPI, are meant to reflect the relative severity of geologic problems in one cell as compared to another, and, indirectly, the difficulty and/or expense involved in safely developing a given area. None of the categories are by themselves intended to imply that the area involved cannot or should not be developed. An additional note of caution should be injected in that - while most natural hazards were considered - flood hazard was not included in this section because this important subject warranted a separate study. (See Flood Control Chapter, p.157.)

Because ground rupture from fault offset is a nearly insurmountable problem, and hence is decisive by itself, it has been treated separately. Furthermore, faults have a linear rather than areal distribution, and, as a consequence, are not well adapted to grid cell analysis. Although a number of faults have been classified as active in this study, known ground rupture in the County due directly to faulting during historic time is limited to one or two locations, including creep along the Mesa Fault.

A bar graph has been prepared (Figure 20) showing the percentage of cells of each of the five severity categories for each of the five computer analysis areas. It should be noted that the County-wide GPI distribution will not be the sum of the distributions in the four study areas because these areas are not of equal size and comprise only a small fraction of the entire County. It is also possible to have a higher GPI in a study area than is shown on the County-wide GPI map. Because of the different sizes of the cells on the respective maps, a small parcel in a study area with a high GPI may not appear on the County-wide map.

As can be seen in Figure 20 and on the GPI Maps, over 90% of the Lompoc and Santa Maria computer analysis areas have been rated

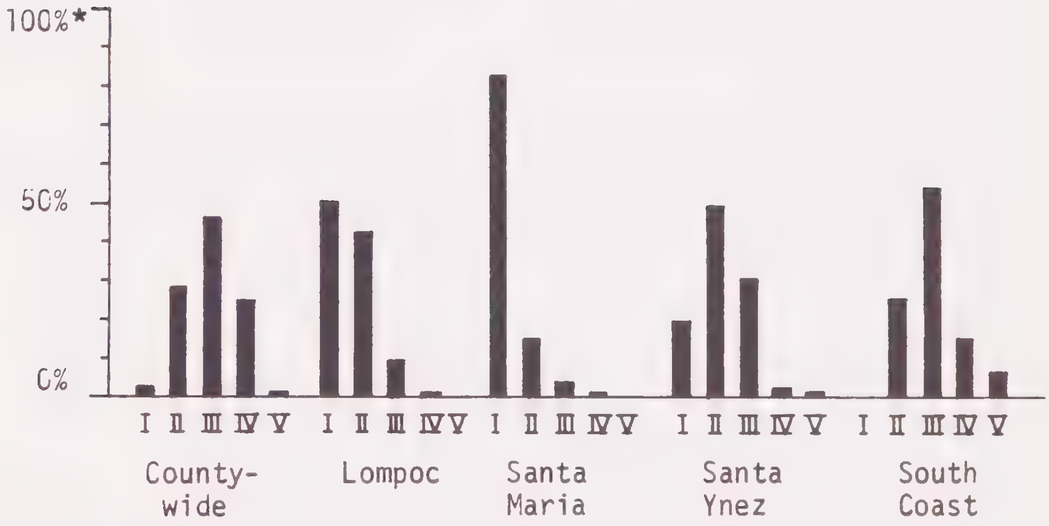


FIGURE 20

DISTRIBUTION OF SEVERITY
CATEGORIES OF THE GEOLOGIC
PROBLEM INDEX FOR THE FIVE
COMPUTER ANALYSIS AREAS

* Percentage of area falling in severity category

with geologic problems of only low or low-moderate severity. These two areas are relatively flat, eliminating problems of slope instability (landslides) or soil creep. The granular soils found in these areas are generally at worst only moderately expansive. Limited areas have high groundwater and possibly compressible soils, and may be subject to liquefaction. Lompoc and Santa Maria share primarily a moderate problem rating for ground shaking, and only very small portions of these two computer analysis areas might be subject to risk of tsunamis.

The Santa Ynez computer analysis area is very similar in topography and geology to Lompoc and Santa Maria, but only 68% of the area has been rated less than moderate. Although there is a slightly higher incidence of high groundwater and attendant possibility of liquefaction in the Santa Ynez area, the main reason for the higher GPI's is a ground shaking problem rating of high (3) over much of the computer analysis area.

The South Coast computer analysis area has the most problem of the urban areas, with approximately 75% of the area moderate to severe. The flatland areas have generally similar GPI's to the other flatland areas in the County, but since nearly all of the South Coast has a ground shaking problem rating of high (3), there are no cells in the South Coast with a GPI falling in the low severity category. The areas with a GPI severity worse than moderate are basically the hillsides and the coastal lowlands. Coastal lowlands with high groundwater and compressible soils, and hence a possibility of liquefaction. and also with possible risk of tsunamis, have a GPI value falling in the moderate-severe category. accounting for perhaps half of the 15% of the South Coast in this category. The remainder of the area with a moderate-severe GPI and the majority of the approximately 6% of the South Coast with a GPI in the severe category, are located on the hillsides, where the geologic formations that occur are prone to landslides or slope stability problems, along with expansive soils and soil creep.

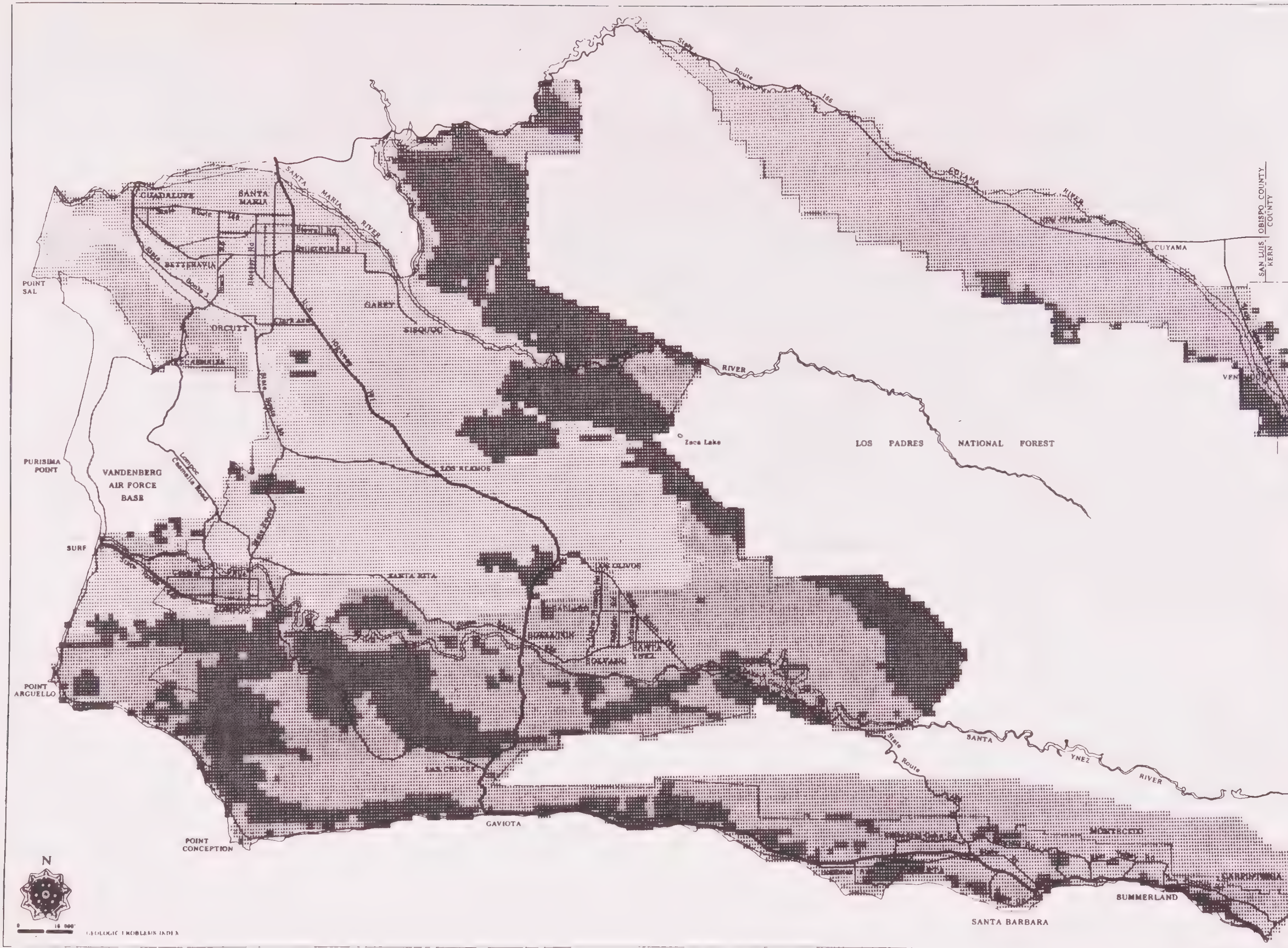
On the County-wide map, the distribution of GPI's is fairly evenly balanced on either side of the moderate category, with all varieties and combinations of geologic problems occurring in different areas. There are very few cells on the County-wide map with a GPI falling in the severe category, because of the previously mentioned difficulty in rating localized severe problem areas at the County-wide scale of 1" = 8000'.

Uses of Severity Map

In all the work connected with the input data and methods of computation and categorization leading up to the GPI severity maps,

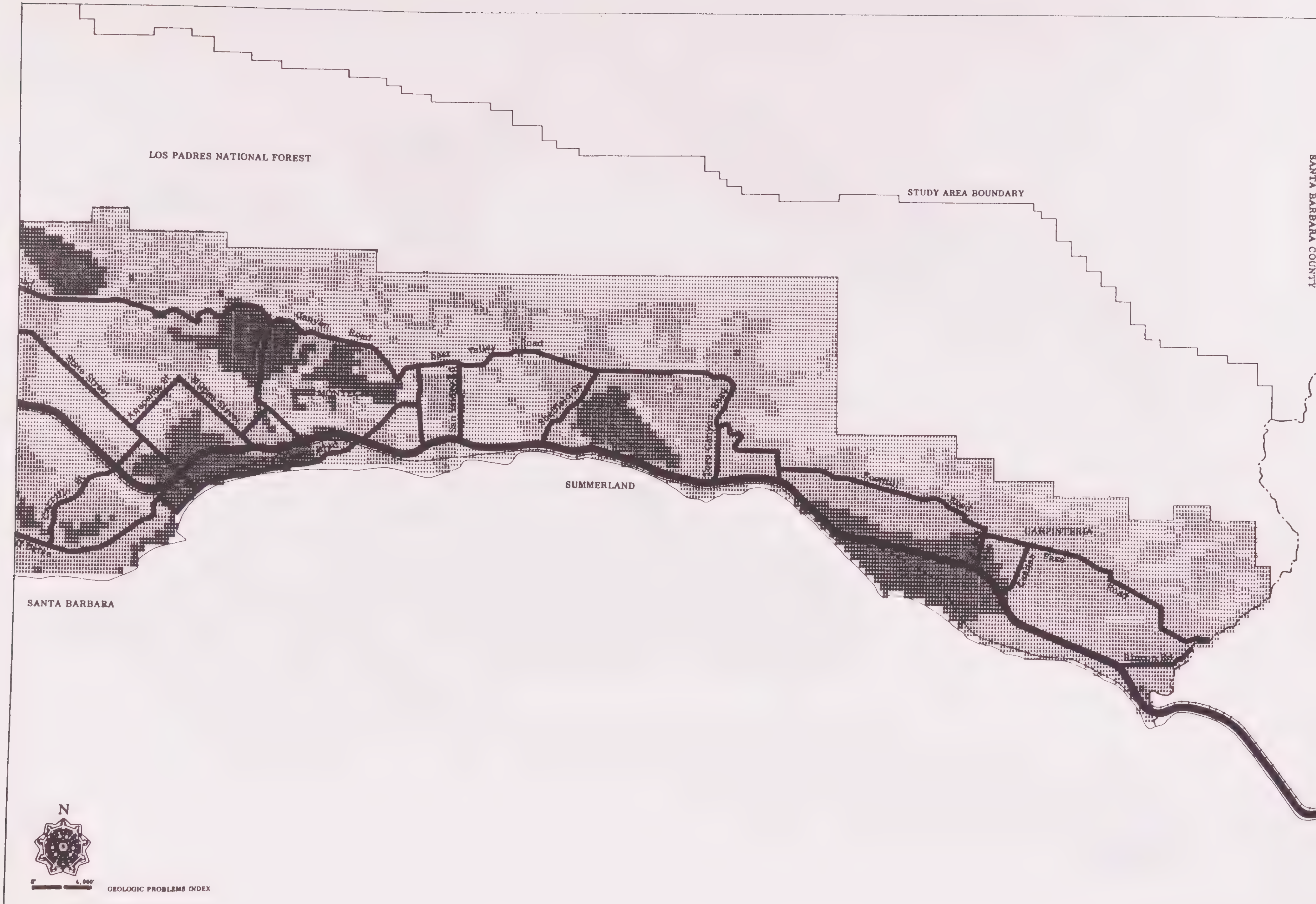
Santa Barbara County
Geologic Problems Index

Category	Problem Severity	GPI Range
I	Low	100-125
II	Low-Moderate	126-145
III	Moderate	146-180
IV	Moderate-Severe	181-210
V	Severe	211 Up


State Route 166
CUYAMA RIVER
NEW CUYAMA
CUYAMA
SAN LUIS OBISPO COUNTY
KERN COUNTY
GUADALUPE
SANTA MARIA
SANTA MARIA RIVER
POINT SAL
ORCUTT
GAREY
SISQUOC
RIVER
Zaca Lake
LOS PADRES NATIONAL FOREST
PURISIMA POINT
VANDENBERG AIR FORCE BASE
Lompoc Casmalia Road
LOS ALAMOS
SURF
SANTA RITA
LOS OLIVOS
SANTA YNEZ
VENTURA COUNTY
POINT ARGUELLO
State Route
SANTA YNEZ RIVER
GAVIOTA
POINT CONCEPTION
MONTECITO
SUMMERLAND
CARPINTERIA
SANTA BARBARA
N
0
GEOLOGIC PROBLEMS INDEX

South Coast Study Area ~ East
Geologic Problems Index

Category	Problem Severity	GPI Range
II	Low-Moderate	126-145
III	Moderate	146-180
IV	Moderate-Severe	181-210
V	Severe	211 Up


LOS PADRES NATIONAL FOREST
STUDY AREA BOUNDARY
VENTURA COUNTY
SANTA BARBARA COUNTY
SUMMERLAND
CARPINTERIA
SANTA BARBARA
N
0' 4,000'
GEOLOGIC PROBLEMS INDEX

South Coast Study Area ~ West
Geologic Problems Index

Category	Problem Severity	GPI Range
II	Low-Moderate	126-145
III	Moderate	146-180
IV	Moderate-Severe	181-210
V	Severe	211 Up


State Route 154
COMPUTER ANALYSIS AREA BOUNDARY
U.S. HIGHWAY 101
ELLWOOD
UCSB
SANTA BAR
U.S. HIGHWAY 101
GAVIOTA
EL CAPITAN
N
GEOLOGIC PROBLEMS INDEX

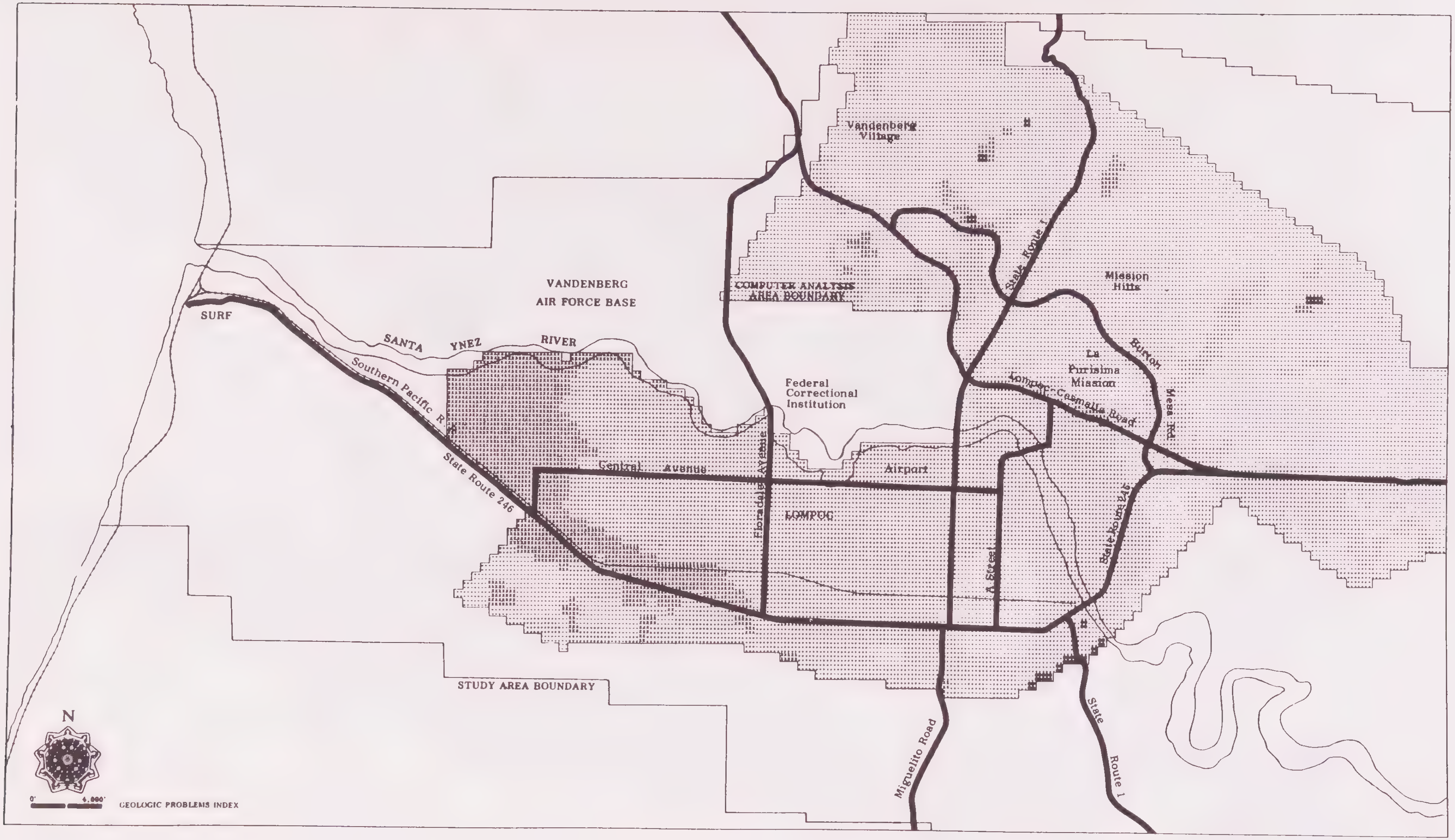
Santa Ynez Valley Study Area
Geologic Problems Index

	Category	Problem Severity	GPI Range
	I	Low	100-125
	II	Low-Moderate	126-145
	III	Moderate	146-180
	IV	Moderate-Severe	181-210
	V	Severe	211 Up

COMPUTER ANALYSIS AREA BOUNDARY
STUDY AREA BOUNDARY
HIGHWAY 101
LOS OLIVOS
BALLARD
SANTA YNEZ
BUELLTON
SOLVANG
Airport
SANTA YNEZ RIVER
Alisal Road
N
0'
4,000'
GEOLOGIC PROBLEMS INDEX

Lompoc Study Area
Geologic Problems Index

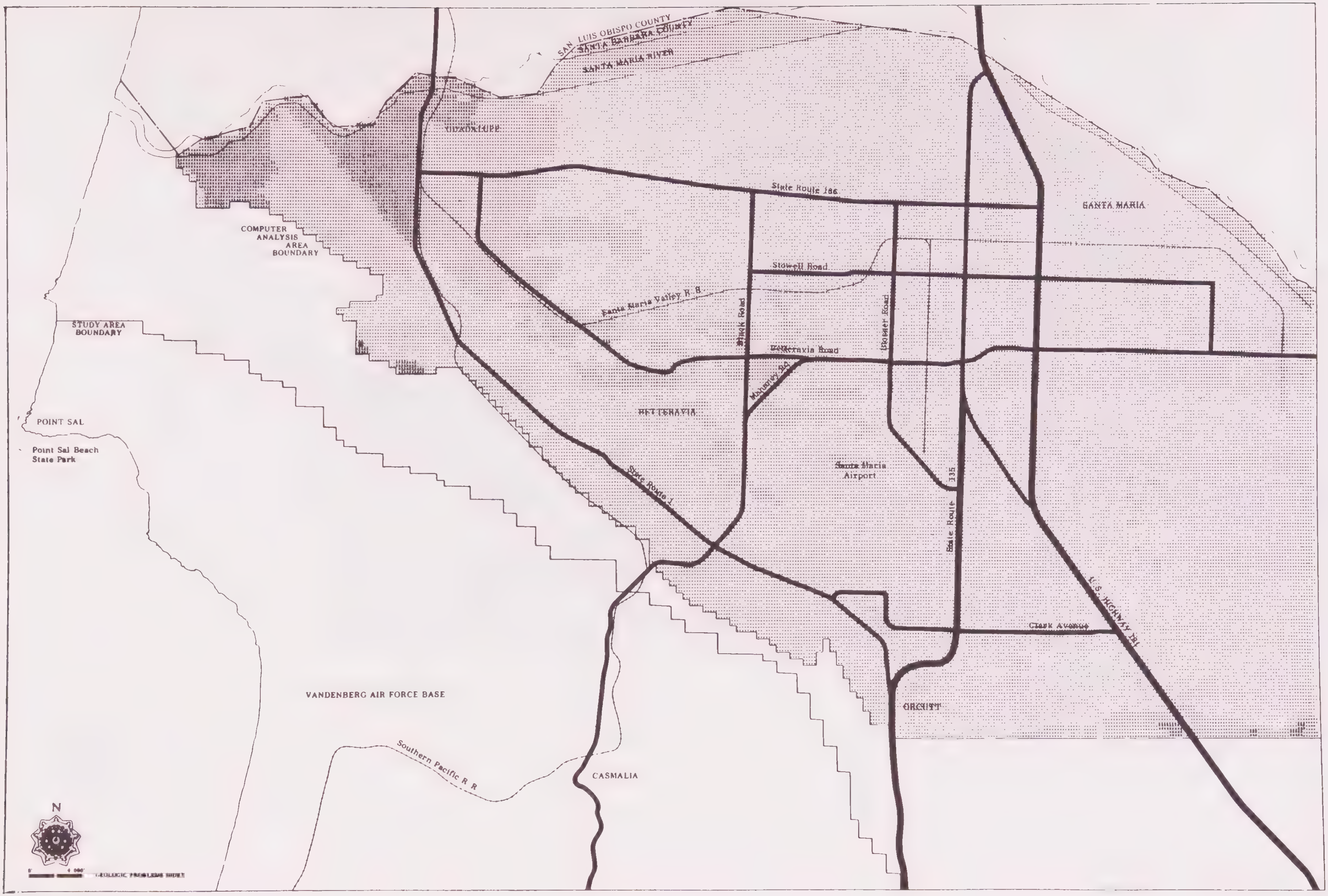
Category	Problem Severity	GPI Range
I	Low	100-125
II	Low-Moderate	126-145
III	Moderate	146-180
IV	Moderate-Severe	181-210



Vandenberg Village
COMPUTER ANALYSIS AREA BOUNDARY
VANDENBERG AIR FORCE BASE
SURF
SANTA YNEZ RIVER
Southern Pacific R.R.
State Route 246
State Route 1
Mission Hills
La Purisima Mission
Burton Mesa Rd.
Lompoc-Casmalia Road
Federal Correctional Institution
Central Avenue
Floradale Avenue
Airport
LOMPOC
A Street
State Route 246
STUDY AREA BOUNDARY
Miguelito Road
State Route 1
N
0'
4,000'
GEOLOGIC PROBLEMS INDEX

Santa Maria-Orcutt Study Area
Geologic Problems Index

	Category	Problem Severity	GPI Range
	I	Low	100-125
	II	Low-Moderate	126-145
	III	Moderate	146-180
	IV	Moderate-Severe	181-210



SAN LUIS OBISPO COUNTY
SANTA BARBARA COUNTY
SANTA MARIA RIVER
GUADALUPE
State Route 166
SANTA MARIA
COMPUTER
ANALYSIS
AREA
BOUNDARY
Stowell Road
Santa Maria Valley R R
Black Road
Betteravia Road
STUDY AREA
BOUNDARY
Mahoney Rd
POINT SAL
Point Sal Beach
State Park
BETTERAVIA
Santa Maria
Airport
State Route 1
135
State Route
U.S. HIGHWAY 101
Clark Avenue
VANDENBERG AIR FORCE BASE
ORCUTT
Southern Pacific R R
CASMALIA
N

attempts were made to make the net result as absolute as possible, so that an area rated moderate had moderate geologic problems in an absolute sense, not just relative to other parts of the County. On a broad scale, it is believed that this goal was achieved. However, limitations and inherent problems arose that prevented the application of this rating system in an absolute sense to a single cell, even though on a broad scale the ratings can be viewed as absolute.

In addition to previously described limitations regarding scale and accuracy of available basic data and the somewhat subjective nature of the evaluations and weighting factors, two other things should be kept in mind. First, the indicated variability of the problem ratings should be taken into account; two areas may have the same GPI, but one might have a large variability to the high side and the other to the low side. Secondly, where boundaries between different problem ratings pass through a cell, the rating chosen was the one which covered 50% or more of the area of the cell. The error in this generalization is obvious.

In spite of these conditions, we believe that the time and effort spent to develop the GPI system for Santa Barbara County has been well spent, and that the product is a very useful one. As a planning aid, it shows the range in occurrence and severity of geologic problems within the County, providing valuable input necessary to the development of an intelligent plan for land use. The individual problem rating maps can be used by developers and by the various governmental agencies responsible for their supervision and guidance as an index to the specific geologic problems that can be expected in a particular area.

COPING WITH THE PROBLEMS

The effects of geologic, soil and seismic problems and hazards can be minimized or eliminated only with a multiple approach; no single procedure is the solution. Some problems, such as landslides, can (in general) be prevented by appropriate design; others such as ground offset along faults during earthquakes cannot. However, earthquake risks (ground rupture and ground shaking), along with the other problems, can be minimized by the following basic procedures:

> Appropriate planning so that the areas with high risk problems of an unsolvable character (such as ground rupture) are either not developed with structures or are developed at a low density and subject to strict design requirements.
>
> Adequate Grading and Building Codes so that damage is minimized.

LAND USE PLANNING

Land use planning should strive for the following objectives:

1. Avoid construction of buildings of all types and most structures on or across historically active or active faults. (This is not always possible with long linear structures or facilities such as utility lines, roads, irrigation canals, etc., but certain safety features such as shut-off valves, can be required to minimize damage and expedite repair.) The appropriate setback distance from the trace of the fault would be variable, depending on the conditions, but normally would be a minimum of at least fifty feet on either side of the sheared zone.

2. Avoid locating critical structures (hospitals, schools, communication centers, fire and police facilities, dams, nuclear power plants, etc.) on or immediately adjacent to active or potentially active faults. It should be noted that the siting and design of hospitals, schools, and dams are controlled by the State, and nuclear power plants by the federal government, and are thus beyond the jurisdiction of the County.

3. Because active fault zones are not suitable for construction sites, they should be developed for non-structural uses or left in an undeveloped natural state. In view of the normally narrow width of the zone (100 feet minimum) in which building should be avoided, the zone would be a suitable location for trails or narrow green belts, possibly adjacent to residential or commercial areas.

4. Areas designated Category V indicate severe problems. These areas should be given primary consideration for minimum development and use. They could be planned as natural areas, or for recreational, cultivated agriculture, or grazing agricultural use. If development is permitted, it should generally be of low density.

5. Areas designated Category IV indicate lands developable at moderately high cost. These might be left undeveloped or developed - depending on the future requirements for urban land. It should be noted in this regard that low density zoning is not necessarily the answer for all such areas - even though it is generally recommended. For example, areas of large landslides may require substantial sums for correction, which could be economically

feasible only if moderately dense development were permitted. Generally speaking, different types of construction (commercial vs residential, for example) would have no distinct advantage or disadvantage compared to one another in areas in this category, except that commercial or industrial development would generally result in less landscape water entering the soil than medium density residential development.

6. Areas designated Category III would have moderate problems, but would generally be suitable for all types of development.

7. Areas designated Category I and II would have relatively minor problems (except possibly seismic shaking) and would be suitable for all types of development.

8. Slope steepness should be considered as a problem in development along with geologic problems, and would significantly accentuate the problems of a Category IV or V site. The heights of cuts and fills vary depending on the level dimensions of the lots and whether the streets are single or double frontage, but generally become excessive with slopes of approximately 30%. However, if structures are built on slopes using caissons or stepped foundations or if just the ridge tops and canyon bottoms are developed, steeper terrain can be be utilized.

9. Where sewers are not available so that private sewage disposal will be required, densities should be low, particularly in areas subject to landslides and high groundwater.

SUBDIVISION PROCEDURES

In order to efficiently and adequately control land development, it is essential that geologic and soil engineering input be provided in the design of the subdivision maps. Control only at the grading and building permit stage is too late, if conditions exist which could affect the basic tract design.

The importance of a thorough soil engineering and geologic investigation and adequate review at the tentative map stage cannot be over-emphasized. Any problem that might significantly affect tract design should be detected and taken into account at this stage to avoid serious problems for both the County and the developer later. Fortunately, the County has a geological, as well as an engineering staff, to review soil and geologic reports.

Section 21-7(d) (4) and (5) of Ordinance 2199 (County Code Chapter 21) gives the authority to require preliminary soil reports.

In addition, the Director of Public Works may require a geological report of the land involved, including an analysis of the proposed grading plan made by an engineering geologist acceptable to the Director of Public Works. However, the Ordinance is ambiguous as to whether or not this can be required for existing ground where slopes do not exceed 10%; this should be clarified.

As a general rule, we believe that soil investigations should be required for all subdivisions. Geologic reports should generally be required when the property contains or is near an active or potentially active fault or is classified as categories III, IV, or V (moderate, moderate-severe, and severe).

GRADING CODES

Since a high percentage of building damage in Southern California is related to geologic and soil problems, Grading Codes are equally as important as Building Codes. In Santa Barbara County, grading is regulated by Ordinance No. 1795. This is a code roughly equivalent to the Grading Code of the Uniform Building Code (Chapter 70), but is a completely separate document. Both are sound regulations based on considerable study and experience. In our opinion, the Santa Barbara County code generally provides for adequate control as far as geologic problems are concerned where grading is involved.

One of the most important functions of the Grading and Building Codes is to require a detailed geologic and soil investigation of the specific site under consideration. The study is usually made by a private consultant and reviewed by one or more governmental agencies. Site conditions vary greatly, and no code provisions can be applicable to all sites unless they allow for flexibility. The site investigation is essential for all structures of any consequence, and frequently is necessary even for a single-family residence or similar structure if located in an area with possible problems. The County Public Works Department has authority to require geologic and soil engineering reports. We believe that the present requirements are worded broadly enough that they provide justification for requiring consideration of seismic hazards in design of graded slopes

Based on the San Fernando earthquake and ensuing studies and deliberations by governmental agencies and professional societies, Grading Code changes have been proposed. Requirements regarding seismic analysis of slopes have been proposed by a committee of

the Geotechnical Group of the Los Angeles Section of the American Society of Civil Engineers, and have subsequently been adopted by administrative order by Los Angeles County. We recommend adoption of these minimum standards for slope stability analysis by Santa Barbara County. The regulation reads as follows:

> The following minimum standards for slope stability analysis will be required for all fill slopes steeper than 2:1 and cut slopes steeper than 1.5:1.
>
> 1. Separate calculations should be performed for static and seismic conditions.
> 2. The pseudostatic slope stability analysis would be the minimum seismic analysis accepted for design.
> 3. Conventional static methods of slope stability analysis based upon principles of mechanics may be used to analyze the stability of slopes under both static and pseudostatic loads.
> 4. The minimum acceptable factor of safety on shear strength is 1.5 for static loads and 1.1 for pseudostatic loads. The factor of safety on strength is defined as the ratio of the shearing resistance force to the actual driving force acting along the potential failure surface.
> 5. The analysis should include the effect of soil weight and seepage or pore pressure where applicable to the analysis (saturation condition for fill).
> 6. Pseudostatic loads should include the effect of static loads combined with a horizontal inertial force acting out of the slope and through the center of gravity of the potential sliding mass.
> 7. A minimum pseudostatic horizontal inertial force equal to 0.15 times the total weight of the potential sliding mass should be used. This value should be increased where the proximity to active faults and the subsoil or geologic site conditions dictate in the opinion of the private consultant(s).
> 8. Potential failure surfaces may be composed of circles, planes or other shapes considered more appropriate to the soil and geologic site conditions.
> 9. The critical potential failure surface having the lowest factor of safety on strength should be sought for the static case. This static surface may be assumed critical for the pseudostatic case.
> 10. Soil properties including unit weight and strength parameters (cohesion and friction angle) may be based on conventional field and laboratory tests. It is expected that the engineer will use considerable judgment in the selection of appropriate shear tests and in arriving

at strength characteristics appropriate to the present and anticipated future slope conditions.

The above analysis for seismic conditions is not required for fills 2:1 or flatter or cuts 1.5:1 or flatter. Pseudostatic loads are dynamic loads converted to an assumed equivalent static load.

With regard to other sections of Ordinance No. 1795, we have the following comments:

Section 7. Definitions - We recommend that "certify" or "certification" be redefined to include the provision of a written geologic engineering opinion as well as merely making reference to tests, because many of the certifications required elsewhere in the Ordinance refer more to engineering analyses, judgments, and opinions than they do to specific test results. "Engineering geologist" should be redefined to correspond with the present State Geologist Act.

Section 16. Inspection and Grading Certificate - We recommend that a certification be required to be signed by the grading contractor stating that he has complied with all of the plans and specifications (as modified, if changes were approved). It is inconsistent not to require a certification from the party actually doing the work, who agrees to perform it in accordance with the plans and specifications but has the most to gain by cutting corners. Such a statement has been required by Ventura County for some time.

Section 22. Excavations - We recommend that item (a) be revised to require that a cut not be steeper than 2 horizontal to 1 vertical, but to retain the condition that a cut may be steeper if recommended by a soil engineering or engineering geology report. The trend gradually is toward limiting slopes to 2:1, and we believe that this is a good principle provided that the responsible governmental agency permits exceptions in the numerous cases where warranted.

Section 24. Planting - Consideration should be given to requiring watering and maintenance in addition to planting of slopes.

Section 25. Building Setbacks and Construction - We believe that item (a) (1) prohibiting building foundations adjacent to slopes, and hence on slopes, is overly stringent. Foundations on slopes have been permitted elsewhere in California, and the performance record is good. This is because deep footings on slopes are specially designed by engineers, and sloping ground permits less water infiltration than flat pads. We suggest, that exceptions be

allowed when justified by special geologic and engineering studies. The County should also consider adopting the building setback table of the Uniform Building Code.

Section 26. Drainage and Erosion Control - Under this section item (a) requires that interceptor terraces have an 8-foot width and be completely concreted. Although we concur with the bench width, we do not believe that the entire bench need be paved unless unusually heavy flows are anticipated. Leaving an outer lip of approximately 2 feet free of contrete would permit planting of bushes or trees, which might add stability by virtue of their root systems, as well as enhancing the project's apprearance. Types of plants should be chosen that would not affect the integrity of the drain.

BUILDING CODES

The design of structures to resist earthquake forces is a very critical factor in their ability to withstand severe earthquakes without structural failure or collapse. Although seismic shock waves can act in any direction, design concern is usually focused on lateral (horizontal) forces because buildings are inherently much weaker with respect to horizontal forces than they are to vertical forces.

Santa Barbara County uses the Uniform Building Code (UBC) to control building design and construction. The 1976 Code has been changed to up-grade lateral force requirements. This change will result in safer structures and reduced potential loss of life at a relatively modest increase in cost compared to the total cost of the structure.

This recommendation does not consider hazards to existing structures due to a severe earthquake. Identification and analysis of this problem should be performed as soon as possible.

LAND STABILITY INSURANCE

Experience has shown that distress or damage to structures will occasionally occur even with good planning, stringent codes, and the best efforts of private geological and engineering consultants and professional personnel of the regulatory governmental agencies. This may be due to one or more of the following factors: limitations in the state-of-the-art of engineering geology and soil engineering, mistakes in judgment or oversights, the variable nature of subsurface conditions, or inadequate maintenance of surface drainage by the occupant after construction is completed. Such problems may be statistically few, but can be catastrophic to those involved.

A logical answer to this problem is some form of insurance against land movement. Such insurance coverage was dropped by conventional insurance companies as a standard part of homeowner's policies after the infamous Portuguese Bend landslide in Palos Verdes in 1956, which destroyed approximately 150 homes. It was completely unavailable for many years, until relatively recently when a speciality company was formed to provide such coverage. Subsequently at least one other company has moved into the market.

Coverage on the average value house probably would cost in the $20-$40 per year range for a five-year policy (substantially less than the cost of fire insurance). A requirement that such insurance be provided by the developer for a period of approximately five years would seem to be a logical procedure and is recommended. This would protect not only the homeowner but also the County, since governmental agencies issuing grading or building permits have come increasingly under attack in the courts in the last few years when damage has occurred.

VI. Fire Hazard

INTRODUCTION

Every summer Santa Barbara County residents live with a wildfire problem that is unique in the world. On dry, extremely windy summer days, the woodland, brushland, and chaparral and grasslands become volatile tinder boxes. A carelessly built campfire, a spark from a chimney or from an off-road vehicle, a fallen power line, or an arsonist's torch can start a fire that will spread across thousands of acres in thirty to forty hours, if unchecked. In these circumstances, the threat to life and property is enormous. Only because California has the best financed and equipped fire protection organization in the world has the potential destruction from wildfires been minimized. The threat, however, persists. If present fire management practices continue, County residents can expect fewer but larger fires to occur in the future. Unfortunately, most of the County lies within an area of extreme fire hazard, and very few areas are immune from wildland fire hazards.

To understand Santa Barbara's problem, first the causes of wildland fires and the County's fire history are reviewed. Then the fire hazard severity classification system developed by the State Division of Forestry is explained, and its application to the County is described. Finally, the topics of fire prevention and control are analyzed in relation to land use planning.

CAUSES OF WILDLAND FIRES

Over 90 per cent of wildland fires are caused by man. Each year only a very few fires are started by lightning throughout the state. By far the greatest number of fires are the result of human carelessness and insensitivity to wildland fire danger, especially during the critical days of the year when the fire problem is most acute. Arson is a second important cause of wildfires, accounting for 22 per cent of all fires recorded state-wide as well as for 22 per cent of all fires burning more than 5,000 acres, termed "conflagrations" by the State Division of Forestry. Despite the criminal penalties, the incidence of deliberately set fires has been rising state-wide at a rate greater than that of population growth. In 1970, incendiarism and arson are estimated to have caused $25 million in property loss, $5 million in additional fire suppression costs, and several lives lost, according to the State Resource Agency's Task Force on California's Wildland Fire Problem.

Power line failure has been cited as another important cause of California fires that burned over 5,000 acres. The high winds that can blow a fire out of control so quickly also can bring down power lines or cause breaks in distribution lines. While more than 23 per cent of conflagrations in the state are considered to be caused by power line failures, only 3 per cent of <u>all</u> fires are attributed to this cause.

Two other major causes of wildland fires are debris burning and "machine use". More than 6 per cent of all conflagrations statewide originated with debris burning in incinerators, at dump sites, or at land development or construction sites. The category of "machine use" includes off-road recreation vehicles, construction equipment, and other power-driven equipment used in industry, agriculture, and recreation. Together, machines and mechanical equipment caused close to 16 per cent of the state's conflagrations in the past 10 years (Task Force on California's Wildland Fire Problem, 1972). Finally, it has been noted that over one third of all wildland fires originate alongside roads and highways, probably as a result of cigarettes or matches being thrown from cars and trucks.

Wildland fires also can originate in developed areas. A leading cause of fires in suburban and rural areas has been children playing with matches. Bonfires or rubbish burning or sparks from chimneys are often cited as sources of wildland fires. During critical fire weather, a small structural fire can spread quickly to adjacent brush and timber lands.

HISTORY OF WILDLAND FIRES

For statistical purposes, the U.S. Forest Service records all fires that burn on or pose a threat to National Forest lands or other lands under protection, and that require suppression effort to control.

From 1911 to 1973, approximately 525 fires were recorded by the Forest Service that occurred within the Santa Barbara County. Of this total, 67 burned 300 acres or more. The average size of these fires in this period was 11,580 acres. However, the average size during the first 30 years was 7,740 acres, while in the period since 1934 the average size was 16,390 acres - more than double the previous average. During the latter time period, the annual fire frequency dropped by over 60 per cent. Over the full 63 year period, one fire occurred on the average every year. However, during the first 30 years approximately 1.6 fires occurred each year while during the last 33 years the rate fell to 0.55 fires per year. Table I summarizes the recorded fire size distribution and historical trends in Santa Barbara County, according to the classifications of the California Division of Forestry.

If the data on individual fires are examined closely, an increase in the frequency of fires burning more than 30,000 acres also is evident. From 1911 to 1931, three fires burned over 30,000 acres. In the next 20 year period only one fire over 30,000 acres was recorded, while in the last 23 year period four fires burned more than 30,000 acres each. These data indicate that in the absence of small fires the likelihood of large fires (conflagrations over 5,000 acres) increases because the brush and hardwood age, thereby increasing hazardous fuel loadings on hills and mountainsides and in canyons.

TABLE 1. RECORDED FIRE SIZE DISTRIBUTION AND HISTORICAL TRENDS IN SANTA BARBARA COUNTY

		Number of Fires by Class			
Time Period	Acreage Burned	300-1,000 Acres Burned	1,000-5,000 Acres Burned	over 5,000 Acres Burned	Total
1911-13	17,060	8	1	1	10
1914-16	2,460	4	-	-	4
1917-19	3,135	1	1	-	2
1920-22	83,880	2	3	3	8
1923-25	92,475	1	4	2	7
1926-28	72,690	2	6	3	11
1929-31	8,053	1	1	1	3
1932-34	30,800	-	-	1	1
1935-37	4,800	-	1	-	1
1938-40	7,965	-	2	-	2
1941-43	2,000	-	1	-	1
1944-46	14,325	-	2	1	3
1947-49	0	-	-	-	0
1950-52	13,920	-	1	1	2
1953-55	158,694	1	-	2	3
1956-58	0	-	-	-	0
1959-61	800	1	-	-	1
1962-64	68,685	1	1	1	3
1965-67	98,065	1	1	1	3
1968-70	0	-	-	-	0
1971-73	15,638	-	1	1	2
1974-76	1,515	-	1	-	1
1977	12,630	1	1	1	3
Total	709,560	24	28	19	71

Source: U.S. Forest Service

Major historic fires burning more than 20,000 acres are listed in Table 2, along with the total acreage burned.

TABLE 2. MAJOR HISTORIC FIRES IN SANTA BARBARA COUNTY

Year	Fire	Acres Burned
1922	Kelley Ranch	59,600
1923	Oso Canyon	70,000
1928	Aliso Canyon	42,880
1933	Indian Canyon	30,800
1953	Big Dalton	73,450
1955	Refugio	84,770
1964	Coyote	67,000
1966	Welman	93,600

Source: U.S. Forest Service

In contrast to these large fires, the Sycamore fire of July 26-27, 1977 only burned 805 acres. Yet the cost was over $30 million, with 216 homes destroyed and 64 others damaged. The December 20-21, 1977 Vandenberg AFB fire burned over 10,000 acres and caused three deaths. Wildland fires in Santa Barbara County clearly have had a tremendous impact over the past 60 years. If present trends continue, the County is likely to experience fewer, larger fires in the future. However, opportunities exist for the County to influence these trends, and these will be discussed in the section on Control Measures. First, a system for identifying fire hazard areas in the County will be presented.

FIRE HAZARD AREAS

To assist land use planners to identify areas of high fire hazard, the State Division of Forestry published a report on Fire Hazard Severity Classification System for California's Wildlands in 1973. The Division's systematic approach to the wildland fire problem was utilized in conjunction with the County Fire Department's and U.S. Forest Service's maps of fire hazard areas in preparing the County-wide Fire Hazard map for this report. The availability of more detailed data on vegetation and slope permitted a finer delineation of areas of fire hazard than had been possible previously.

Three principal factors determine an area's fire hazard severity classification: fuel loading, fire weather, and slope. The first factor, fuel loading, takes into account the age, type, and density of vegetation as well as the mix of living vegetation and deadwood or debris, and usually is represented by an index of tons per acres for each age-type class. Because County-wide data on age and density of vegetation are not available, vegetation alone was taken as the proxy measure for potential fuel loading in preparing the Fire Hazards map. Three levels of fuel loading severity in the County were assumed. Grasslands, with an assumed average fuel loading of 2.2 tons per acre, were classified as light and assigned a fuel severity index of 1. Scrub brushlands and light chaparral have been combined in order

to form the second category of medium fuels, with an assumed average fuel loading of 17.3 tons per acre and a fuel severity rating of 8. The heavy fuels include scrub oak, woodlands, and forest, with an assumed average fuel loading of over 36 tons per acre and a fuel severity index of 16. The estimates of average fuel loading for major vegetative types were based on a study of fuel loading in southern California conducted by the State Division of Forestry in 1955. The specific vegetative types studied and their average fuel loadings correlate closely with the vegetative types found in Santa Barbara County that have been previously listed in the chapter on Ecological Systems in the Conservation Element.

The fire weather concept is characterized by an index representing the expected number of critical fire weather days. The State Division of Forestry's historical record for each of its 151 Fire Danger Rating Areas provides background data from which these index numbers were derived. Of the three classes of critical fire weather frequency in California, only the top two occur in Santa Barbara County. In areas ranked as Class II, the critical fire weather frequency is termed high because from 1 to 9.5 critical fire weather days per year are likely to occur. In any area where the annual average of critical fire weather days exceeds 9.5, the fire weather severity is judged to be extreme, and a Class III designation is assigned. In the County, areas falling in Class II, which are indicated on the Fire Hazard map, include lands mapped on 10 U.S. Geological Survey 7.5 minute quadrangles: Carpinteria, Santa Barbara, Goleta, Dos Pueblos, Tajiguas, Gaviota, Hildreth, Little Pine Mountain, Big Pine Mountain, and Santa Maria. The remainder of the County lies in Class III.

In conjunction with the California Interagency Wildland Fire Danger Rating System, Fire Occurrence Indices and Burning Indices were developed by the State Division of Forestry for each of the state's Fire Danger Rating Areas and combined into a daily Fire Load Index. The cutoff point between the High (or Class II) and the Extreme (or Class III) critical fire weather frequency classes was assigned after careful analysis by the Division of Forestry's experts. It turns out that in Class III areas the average Fire Load Index is five times greater than the average Fire Load Index in Class II areas, a clear indication of the greater hazard associated with a Class III designation.

Topography, the final factor included in the fire hazard severity classification system, is important not only because fires spread more quickly on steeper slopes, but also because fire control is so much more difficult in rugged terrain. Generally, fires spread more rapidly up a slope than down a slope, except in rare instances when the fuel loading and fire weather combine to produce conditions where fires spread equally quickly up and down slopes. Slope factors in the context of the fire hazard severity classification system modify critical fire weather frequency values and fuel loading values; the greater the slope, the greater the multiplier of severity.

All other factors being equal, a slope from 40 to 60 per cent would have a multiplier of 1.6, and a slope over 60 per cent would have a multiplier of 2.0 for purposes of computing a Fire Hazard Severity Index.

The results of applying this rating system to the County are shown on the Fire Hazards map. Three areas of fire hazard are identified. Areas exposed to moderate fire hazard include existing agriculture, grasslands with a Class II or High Critical Fire Weather Frequency classification, and grasslands with a Class III or Extreme Critical Fire Weather Frequency classification and where the predominant slope is less than 40 per cent. Scrub and woodlands with less than 40 per cent slope that fall within the boundaries of the Critical Fire Weather Frequency Class II were classified as high fire hazard areas. Except for existing urban areas, which were not included in the analysis of wildland fire hazards, all of the remaining land in the County is exposed to extreme fire hazard.

According to the State Division of Forestry's fire severity classification system, much more of the County is exposed to fire hazards than had been indicated previously on the County Fire Department's map of "high hazard areas". On the County's official map, all of the land outside National Forest boundaries lying north of the Santa Ynez River and northwest of Buellton and Solvang was excluded from the high hazard areas. However, on the County-wide Fire Hazards map, it can be seen clearly that most of this area has been classified in the extreme fire hazard category, with the remaining non-urban portions indicated either in the high fire hazard or moderate fire hazard category.

CONTROL MEASURES

Control measures designed to reduce fire hazards within the County must be comprehensive rather than single purpose. Efforts should be aimed at minimizing the occurrence of fires and containing fires once they start, but equally important is reducing fuel loadings and exposure of vulnerable land uses and buildings to wildfires. A program to cope with the wildland fire problem should include five major activities: fire prevention, fire control, fuel management and hazard reduction, land use planning, and building codes, and construction materials requirements.

One important control measure designed to reduce the rate of spread and extent of wildland fires is the fuelbreak or firebreak system. The existing and proposed fuelbreak systems developed by the U.S. Forest Service for the National Forest are shown on the Fire Hazards map. Over 87 miles of fuelbreaks, of which 17 miles on the South Coast have been created by wildfires, currently are established.

Santa Barbara County
Fire Hazard

Critical Fire Weather Frequency Classification Boundary

Extreme Hazard Area

High Hazard Area

Moderate Hazard Area

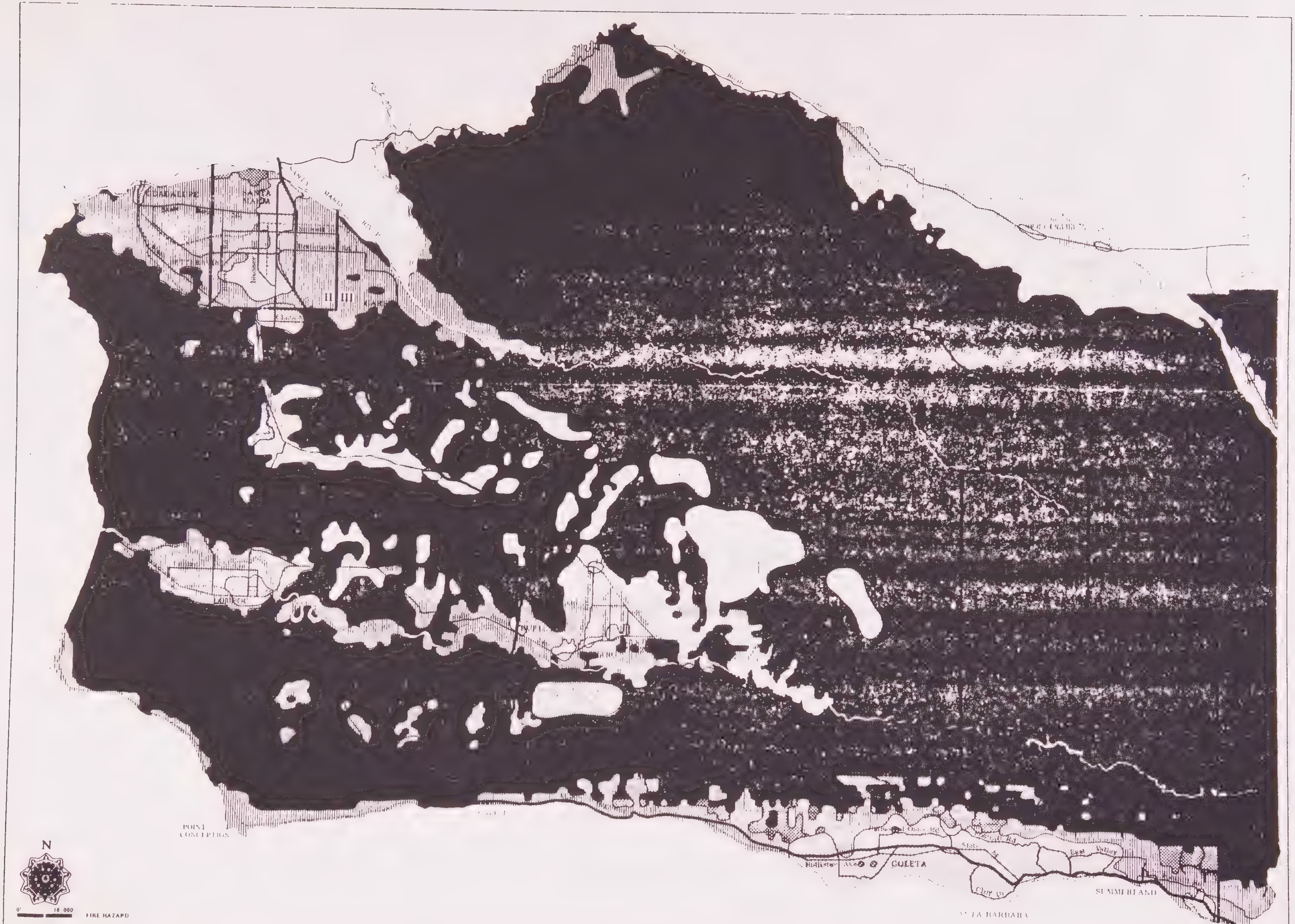
No Hazard

Existing Forest Service Fuelbreak

Proposed Forest Service Fuelbreak

Fuelbreak Created by Wildfire

Urban Development


N
FIRE HAZARD
GOLETA
SUMMERLAND

The Forest Service eventually intends to add 217 miles of fuelbreaks. Outside of the National Forest, the County does not have an organized system of fuelbreaks primarily because of complex multiple ownership patterns and difficulties in securing owners' cooperation, according to the County Fire Prevention Officer. However, a significant number of fuelbreaks have been established by the initiative of some of the large property owners.

Other fire prevention measures that the County has adopted are derived mainly from the Uniform Fire Code. Currently, the County has the authority to regulate the location of bulk storage tanks such as are used to store gas and oil. In addition, bonfires and outdoor rubbish fires are allowed only under permit, incinerator burning is restricted to certain hours, and spark arrestors are required on all chimneys. Open flame devices are prohibited in hazardous fire areas except by permit. Also, in fire hazard areas, firebreaks 30 to 100 feet wide around structures are required in order to minimize the risk of property damage and to improve accessibility in case of fire. The width of the firebreak is set by the County Fire Chief in each case depending on the degree of hazard.

Another fire prevention measure that has been used successfully in many areas of the state is controlled burning. Currently, there is no County-directed program of controlled burns to reduce fire hazard. However, much has been accomplished through the activities of the Range Improvement Association, an organization of ranchers in the central and northern portion of the County and in the Cuyama Valley. The Association submits plans to the County Fire Department for controlled burns aimed mainly at restoring lands for grazing. Fuelbreaks are established as part of the controlled burns. The County Fire Department assists by reviewing the burn proposals, inspecting the fuelbreaks, and making personnel available to assist the Association during the burns.

The concept of fire and fuel management incorporating controlled burning has been extensively studied by research foresters of the U.S. Forest Service. One program, outlined by Dr. Charles W. Philpot at a symposium in 1973, involves a five step approach to fire management. He proposed that a program of fire management be instituted in conjunction with multiple use planning for recreation and open space functions, as well as for fire management, in order to achieve an acceptable and realistic level of fire occurrence and fire size based on ecological, social, and economic considerations. The intent of this program is to break the large continuous areas of chaparral fuels into mosaics of different aged chaparral plant communities by a series of prescribed burns. Thus most of the area would be maintained in the

chaparral ecosystem. Type conversions and fuelbreaks would only be constructed as appropriate to contain the prescribed fires and provide wildfire control. Once this pattern has been achieved, it would be possible to set large planned fires with loosely defined, but predictable boundaries. These fires would be subject to moderate, but not stringent suppression measures as long as they met the goals and objectives of the fire management plan. At the same time, responsible public agencies would continue to improve their suppression and prevention capabilities. Fuelbreak systems would be established to segregate the age-type class boundaries.

The result of this system would be to increase the frequency of fires burning over 100 acres, but to reduce the occurrence of conflagrations after the transitional period during which the program would be instituted. The chaparral ecosystem would be maintained throughout the County, and consequently, watershed damage and flood potential conceivably could be reduced. Dr. Philpot's proposal, which involves acceptance of more fires in the County, should be analyzed in detail to determine whether the potential benefits to the County would outweigh the costs of implementation.

In areas of high or extreme fire hazard, fire protection measures alone will not solve the problem. Land use planning must recognize the hazards and treat them as constraints in the planning process. Under the California Environmental Quality Act, public action is directed to achieve a balance between natural processes and urban uses in order to create and maintain conditions of productive harmony. The law requiring a Safety Element in general plans repeats the same theme in relation to the concept of acceptable and unacceptable risk. Consequently, the County has ample legal authority to regulate land use and development in order to reduce fire hazard.

Land development in fire hazard areas will not only increase the degree of risk by bringing more people into a hazardous area, but also may increase the hazard by altering the vegetation and landform. Whenever brushland is cleared and the debris pushed into piles on slopes or in canyons, the fire hazard during critical fire weather periods is far greater than it has been previously, because the fuel load has been concentrated. On private lands within the National Forest, this problem is complicated by the fact that the Forest Service is not chartered and normally is not equipped to protect structures, its primary mission in this area being wildland fire prevention and control.

Within the National Forest boundaries, development on privately held lands poses a particularly difficult problem. In that portion of the National Forest known as the Santa Barbara Front lying north of the South Coast plain and below the crest of the Santa Ynez Mountains, the issue is especially acute because more than 28,000 acres of mainly contiguous lands within the National Forest boundaries are privately owned. Historically, this mix of public and private ownerships developed when the Forest Service established "Forest

Preserves" that include both publicly and privately held lands within the boundaries of areas designated for watershed protection. As the boundaries were adjusted over time and as acquisition programs proceeded, this problem generally diminished in importance. Today, mixed ownership remains a critical issue only where development pressures persist within the National Forest boundaries. If there had been no development on these lands, in all likelihood the Forest Service would continue to offer the same level of wildland fire protection that it has in the past. Unfortunately, this is not the case. Development on private lands within the National Forest boundaries has occurred in the San Marcos Pass area, around Painted Cave, and at other locations north of Santa Barbara, Montecito, and Carpinteria. If development within the National Forest boundaries continues at the same rate as it has in the recent past, the Forest Service has indicated that it might relinquish its responsibility for wildlands fire protection on the Santa Barbara Front, in which case the responsibility would fall on the County Fire Department.

To alleviate the potential threat that further land development within the National Forest would pose, not only by accelerating the fire-flood cycle but also by increasing erosion, stream encroachment, and adverse ecological impacts, several proposals have been put forward to the U.S. Forest Service and to the County. One alternative, advanced in the 1972 report Santa Barbara Front Development Economic Study, would be for the Forest Service to acquire all of the private land over 30 per cent slope lying within the current National Forest boundary - approximately 23,000 acres. In support of this concept, the Board of Supervisors went on record as encouraging federal purchase of watershed lands within the National Forest. Another approach would be to impose zoning and other development regulations that take into account not only the extreme fire hazard, but also other environmental factors such as flood control and seismic, geologic, and soils problems, along with commonly accepted principles of watershed protection. It also has been proposed that the Forest Service acquire "development rights" from the property owners, as has been done in other National Forest areas, to preserve important scenic values. Clearly, whatever approach that finally is accepted by the County and the Forest Service must take into account the extreme fire hazard on the Santa Barbara Front. The Implementation Program will evaluate alternative development regulations for private lands within the National Forest with a view toward minimizing fire hazard.

Short of prohibiting all land development in areas of extreme fire hazard, the most reasonable solution to this problem, both within the National Forest and elsewhere in the County, is to require that all development proposals be accompanied by a plan showing the measures that will be taken to meet County regulations to minimize fire hazard. Issues that should be addressed include access to the site, water supply, buffer strips and firebreaks around structures, and a contingency plan covering human activities during periods of critical fire weather.

Detailed requirements should be worked out jointly by the County and responsible state and federal agencies. The recommendations of the Task Force on California's Wildland Fire Problem provide useful guidelines for prescribing a specific set of criteria.

In any area of high or extreme fire hazard the cumulative impacts of land development have to be assessed, as well as the individual impacts of specific proposals. In this sense, the issue really is, what is a minimum acceptable area-wide density of human activity throughout the year as well as during critical fire weather periods. Some concerned people have contended that no development, or, at most, no more than one dwelling for each hundred acres should be permitted in areas of extreme fire hazard, while others have advocated densities of one dwelling for each forty acres or one for each twenty acres. Because no definitive studies of this subject have been made and because the circumstances vary greatly from case to case, no overall density standards can be prescribed for extreme fire hazard areas.

When an urban area is adjacent to an area of high or extreme fire hazard, a buffer strip or greenbelt several hundred feet wide can provide the means to contain fires that originate in developed areas and to prevent them from reaching the wildlands. In areas of moderate fire hazard, the greenbelt concept is equally applicable. Greenbelts already exist in the extensive moderate hazard areas used for irrigated agriculture.

Buffer strips can be used, along with the fuelbreak system, for recreation trails and to serve other open space functions, as long as the level of activity anticipated would not increase the fire hazard. During periods of critical fire weather, many activities might have to be curtailed. Opportunities for multiple use of buffer strips and fuelbreaks will be explored in the Open Space Element and the Recreation Element.

CONCLUSIONS AND RECOMMENDATIONS

Wildland fire hazards represent an important constraint that must be considered in the land use planning and development process in order to reduce the risk of occurrence, the potential damage, and the threat of injury or death. Programs for fuel management and hazard reduction, as well as for fire prevention and control, will play an important role in the County's efforts to cope with its wildland fire problem. To further this aim, the County and the cities should adopt the following policies on fire hazards and undertake the recommended studies:

- The County-wide Fire Hazards map should be adopted as the official "hazardous fire areas" map prescribed in County Ordinance 2528 because it shows fire hazard severity in the County more precisely than the present map. Specific regulations for land use and development in fire hazard areas should be revised to reflect the degree of severity in each of the areas indicated on the map.

- All land development (including grading and clearing) in high fire hazard or extreme fire hazard areas should be subject to conditional use permit regulations, and review by the County Fire Prevention Officer and, where appropriate, by responsible federal or State agencies.

- The County should require that land development proposals in each of the fire hazard areas shown on the County-wide Fire Hazards map be accompanied by detailed plans for fire prevention and control prepared in accord with prescribed County regulations. Separate criteria for the preparation of these plans should be prescribed for each of the three fire hazard areas in consultation with responsible federal and State agencies. Once these criteria have been adopted, existing development should be evaluated to determine whether it conforms with the regulations. Owners whose property does not comply with the regulations should be required to make necessary improvements within a reasonable time, or to submit an alternate plan for fire prevention and control that is acceptable to the County Fire Prevention Officer.

- The County should require community firebreaks under Section 21-47 of the Subdivision Regulations in areas of extreme fire hazard rather than leave them up to the discretion of the subdivider. Criteria for judging the adequacy of community firebreaks should be set by the County Fire Prevention Officer.

- The County should initiate a study in cooperation with the U.S. Forest Service to determine what limits should be placed on private development within National Forest boundaries, and to evaluate alternate means to reduce the extent of private inholdings and to phase out existing development if necessary to reduce fire hazard to an acceptable level. Until the study has been completed, all development (including grading and clearing) in these areas should be subject to review under the conditional use permit procedure previously recommended.

- The County should initiate a study in cooperation with the U.S. Forest Service and the California Division of Forestry to determine whether a program of fire and fuel management incorporating controlled burns and a County-wide system of fuelbreaks that would be designed to maintain the chaparral ecosystem would be beneficial to the County. If this program proves feasible, an implementation program also should be prepared.

- The County should review, and, if necessary, revise the Fire Hazards map at least once every two years to take into account new data on recent burns, age-type class boundaries for vegetation, and vegetation density.

VII. Flood Control

INTRODUCTION

Santa Barbara County is traversed by two major rivers (the Santa Maria River and the Santa Ynez River) as well as by numerous tributaries of these two rivers and numerous smaller streams which discharge directly to the Pacific Ocean. These streams are subject to high flows following periods of intense precipitation, and the flood waters resulting from these high flows can impair the suitability of certain lands for various uses.

The extent of damage from flooding can be mitigated by the construction of facilities for the control of flood flows. A federal flood control project has been constructed in the Santa Maria Valley. The amount of the flood peak in the Santa Maria River is reduced by storage of flood waters in Twitchell Reservoir on the Cuyama River (the major tributary of the Santa Maria River). Levees have been constructed on the valley floor to contain the flood waters originating below Twitchell Reservoir as well as the releases from that reservoir.

No major facilities specifically designed for the purpose of flood control exist on the Santa Ynez River. However, a substantial amount of storage is provided for water conservation purposes, particularly in the U.S. Bureau of Reclamation's Cachuma Reservoir. Although this storage is not specifically for purposes of flood control, it does offer incidental flood control benefits. However, this does not provide assured flood protection, and in circumstances such as the 1969 floods which occurred when the reservoir was essentially full, there is very little diminuation of flood hazard.

Improvements to stream channels in the populated portions of the South Coast and Lompoc areas have been built by the Santa Barbara County Flood Control and Water Conservation District, the U.S. Corps of Engineers, and by the U.S. Soil Conservation Service.

In addition to the flood problems resulting from inability of stream channels to convey the full amount of flood flows, localized drainage problems exist in areas where water ponds and is unable to escape sufficiently rapidly to prevent inundation. Among the principal drainage problem areas is a low-lying coastal area in the City of Santa Barbara.

FLOOD HAZARDS

The lands within the County have been classified into eleven categories to assess the extent of impairment of suitability for development due to flood hazard. The County wide and study area maps show the lands in each category. A brief explanation of each of the categories follows.

Category 1, Stream Channels -- Areas were categorized as stream channels if review of U.S. Geological Survey quadrangle sheets indicated that the area drained by the stream is significant. Generally, streams with significant drainage area identified on the quadrangles by name, or canyons identified in a similar manner, were plotted in this category. In most areas, the scale of the maps precluded indication of the channel width. However, major streams, such as the Santa Ynez and the Santa Maria rivers, were plotted with a definite width as indicated on the quadrangle sheets. The specific limits of the area occupied by the stream channel, and of any area to be reserved for protection of the channel, must be established by detailed evaluation of any specific development proposal. Reservoirs also were included in Category 1.

Category 2, Floodway Area -- The floodway is defined in connection with the federal Flood Insurance Program as "the channel or water course, and that portion of the adjacent flood plain required for the passage of the 100-year frequency discharge (discharge having a one percent chance of occurrence) with an insignificant effect on water surface above that of the prefloodway condition." The floodway represents the area into which there should be permitted no enchroachment that would impair the ability to convey flows. Areas in this category generally were defined by the U.S. Corps of Engineers. The floodway plotted is for the once-in-a-hundred-year event; and where no data exist to the contrary, the total area inundated by the 100-year flood was assumed to be in the floodway.

Category 3, 100-Year Flood Plain with Proposed Improvements Constructed -- Category 3 represents the flood fringe for the 100-year flood, i.e., that portion of the flood plain which is outside of the flood-way (Category 2). Where the flood plain can be reduced by proposed flood control improvements, only that portion of the flood plain that will continue to exist after such improvements is included in Category 3. For purpose of categorisation, a reasonable proposed flood control improvement was considered as a project that is presently under construction, that is presently planned, or that has been demonstrated to be feasible by planning studies. Where no reasonable proposed flood control improvement exists, the entire flood fringe area is considered to be in Category 3.

Category 4, 100-Year Flood Plain with Existing Improvements Only -- Areas are shown as being in this category only when the 100-year flood plain may be reduced by additional reasonable proposed flood control improvements, the amount of the reduction in flood plain is known, and the amount of the reduction is of sufficient size to appear on the map. Proposed projects considered are additional flood control improvements on Franklin and Santa Monica Creeks near Carpinteria, and the authorized U.S. Corps of Engineers' flood control project in the Goleta area.

Category 5, Standard Project or 500-Year Flood Plain -- Category 5 represents those lands that are outside the flood plain of the 100-year flood, but that may be inundated by the 500-year flood or the standard project flood. The U.S. Corps of Engineers defines the standard project flood to be that which would result if the maximum storm of record in

Southern California were to be centered over the watershed area of the particular stream being considered, with the watershed in a saturated condition. The standard project flood does not lend itself to frequency evaluation but it is generally considered that the recurrence interval is roughly 200 to 300 years. The Corps of Engineers, in connection with its participation in the federal Flood Insurance Program, has determined the 500-year flood events in some areas of the South Coast. The Corps of Engineers also has defined the flood plain area of the standard project flood on the Santa Ynez River. For stream channels that are deeply incised and have essentially vertical walls of confinement, the difference between the inundated area for the 100-year flood event and the 500-year or standard project flood event is quite small. Accordingly, in many cases, the scale of the maps does not permit definition of the Category 5 areas.

Category 6, Local Drainage Problem Areas with Proposed Improvements Constructed -- Drainage problem areas were distinguished from areas with flood hazard, primarily because problems are less severe and generally can be remedied with a minimum of expense. Building homes on pads or utilizing a minimum amount of grading and land leveling are examples of procedures used to avoid drainage problems. Category 6 is analogous to Category 3. Category 6 areas (as well as Category 7 areas) were defined in consultation with the County Flood Control Engineer and Public Works officials of the cities of Lompoc and Santa Maria.

Category 7, Local Drainage Problem Areas with Existing Improvements Only -- Category 7 bears the same relationship to Category 6 that Category 4 bears to Category 3. Reasonable proposed drainage improvements include those in the cities of Santa Barbara and Santa Maria.

Category 8, No Flood Hazard -- Areas in this category generally are those where flood problems would not be a constraint on development. Areas in this category are located on mesas such as those along the South Coast or in areas with relatively steep slopes, allowing rapid drainage of flood waters. Based on discussions with the County Flood Control Engineer, it was determined that lands above 250 foot elevation in the Carpinteria area would be free from flood hazard. North of Montecito, from Romero Canyon to Cold Spring Canyon, lands above a 750 foot elevation are considered to be free from flood hazard. From Barger Canyon or Arroyo Burro Creek west, lands above 250 foot elevation or the elevation of the base of the hills, whichever is lower, are considered to be free from flood hazard. The limits of other areas classified as Category 8 lands were established on the basis of our judgments. In areas where either the 500-year or standard project flood plains were defined, lands lying outside of these flood plains are considered to be in Category 8, unless it is believed that flood hazards might arise from tributaries to the stream for which the flood plain is defined.

TABLE 3. DISTRIBUTION OF LAND IN FLOOD HAZARD CATEGORIES[a]

Category		(000's Acres)				
		South Coast	Santa Ynez	Lompoc	Santa Maria	County-wide Study Area[c]
1.	Stream channels	8.6[b]	5.7[b]	2.3[b]	6.7[b]	347.5[b]
2.	Area (in addition to Category 1) within floodway of 100-year flood, assuming floodway to occupy entire flood plain in the absence of information to the contrary.	1.7	1.5	3.5	1.2	6.2
3.	Area (in addition to Categories 1 and 2) within 100-year flood plain, after any reasonable proposed flood control improvements are completed. (Assumed to be same as Category 4 in the absence of data to the contrary.)	2.3	0.6	1.3	---	2.7
4.	Area (in addition to Categories 1, 2, and 3) within 100-year flood plain with existing flood control improvements only.	0.6	---	---	---	0.4
5.	Area (in addition to Categories 1, 2, 3, and 4) within standard project flood or 500-year flood plain.	0.3	0.4	0.2	---	0.3
6.	Local drainage problem areas (in addition to Categories 1, 2, 3 and 4) after proposed drainage improvements are completed.	0.2	0.1	---	1.0	1.1
7.	Local drainage problem areas (in addition to Category 6) with existing facilities only.	0.2	---	---	0.9	0.7
8.	Areas without potential flood hazard.	32.8	28.9	14.6	15.8	533.3
9.	Areas outside 100-year flood plain which may or may not be in 500-year or standard project flood plain. (Areas which cannot be classified in Categories 5 and 8.)	8.7	---	4.4	---	6.9

TABLE 3. DISTRIBUTION OF LAND IN FLOOD HAZARD CATEGORIES (CONTINUED) [a]

Category	South Coast (000's Acres)	Santa Ynez	Lompoc	Santa Maria	County-wide Study Area[c]
10. Areas with possible flood hazard not subject to evaluation. (Areas which cannot be classified in Categories 4, 5, and 8.)	3.1 [b]	2.1 [b]	1.5 [b]	3.8 [b]	26.1 [b]
11. Areas with possible local drainage problems, not presently determined. (Areas which cannot be classified in Categories 6, 7,and 8.)	---	5.2	---	39.1	34.8
Total	58.5	44.5	27.8	68.5	960.0

(a) Estimated acreages derived from tabulation of the number of grid cells in each category.

(b) Represents total acreage for all grid cells in which stream channels are located, and not actual acreage occupied by the stream channel.

(c) Includes urban study areas.

Category 9, Areas Which May Be in 500-Year or Standard Project Flood Plain -- Areas in this category generally are those for which flood studies have defined the 100-year event only, and data on standard project or 500-year flood plains are not available.

Category 10, Unknown Flood Hazard -- For many streams in Santa Barbara County, particularly those remote from population centers, data on potential flood hazard are not available. These areas are classified in Category 10. In mountain valleys, Category 10areas are assumed to extend to the base of the surrounding hills. As a prerequisite to development of Category 10 lands, detailed evaluation of flood potential should be required.

Category 11, Unknown Drainage Hazard -- Lands in this category have potential drainage problems which have not been evaluated. Discussions with the County Flood Control Engineer indicate that, as developments take place, special procedures must be followed to resolve problems that may result. These problems manifest themselves in increased downstream runoff, erosion hazard, and inadequate slope to carry away drain water. These areas were defined by the County Flood Control Engineer.

Table 3 summarizes the distribution of areas within each of the eleven flood hazard categories.

DEGREE OF CONSTRAINT ON DEVELOPMENT

The degree of constraint on urban, agricultural, or recreational development of lands in the various flood hazard categories shown below, is presented on a 0-10 scale, with 0 indicating that lands in a particular category are unsuitable for the indicated use, and 10 indicating no constraint on the particular use, at least within the accuracy of a scale of 0 to 10.

TABLE 4. DEGREE OF CONSTRAINT ON DEVELOPMENT DUE TO FLOOD HAZARD.

	DEGREE OF CONSTRAINT ON DEVELOPMENT [a]		
Category	Agricultural	Recreation [c]	Urban
1	1	2	0
2	6	5	0
3	8 [b]	7 [b]	3 [b]
4	8	7	3
5	10	10	9
6	7 [b]	7 [b]	4 [b]
7	7	7	4
8	10	10	10
9	10	10	9 [b]
10	6 [b]	5 [b]	0 [b]
11	7 [b]	7 [b]	4 [b]

(a) 0 = unsuitable, 10 = no constraint.
(b) Could be less restrictive value if necessary improvements are constructed or if the propriety of higher classification is demonstrated by further detailed study.

(c) Represents suitability for intensive recreational use involving substantial improvements.

In this context, recreational development refers to intensive recreation activities requiring substantial physical improvements (e.g., golf courses, campgrounds, intensively developed parks, etc.).

The degree of flood hazard to lands in certain of the categories is unknown. Under these circumstances, the degree of constraint shown in Table 4 is that appropriate for the most severe flood hazard condition which might exist, recognizing that more detailed studies could justify shifting a particular parcel of land to a less restrictive category. Similarly, in certain categories where the extent of flood hazard would be mitigated by the construction of improvements, the degree of constraint on development could be reduced if and when the proposed improvements are constructed. The following paragraphs discuss in greater detail the degree of constraint for the various categories.

Category 1, Stream Channels - Recreational and agricultural usage could be permitted within stream channels. However, such usage would have to be subject to controls which ensure that the activity does not endanger life or property and does not interfere with the integrity of the stream channel for its primary purpose, the conveyance of water. Recreational use such as hiking could be permitted in many stream channels during periods when flows are small or nonexistent. Heavier recreational use, such as golf courses or developed campgrounds, obviously would have to be on a much more restrictive basis. The primary considerations with respect to agricultural use would be limiting it to types that do not impair the stream channel's ability to carry water and that do not involve activities that create erosion problems. In all cases, the extent of the liability which might be assumed by the owner of the stream channel would have to be given heavy weight. Conceivably, necessary restrictions on the use of stream channels would make only light recreational activities practical in most instances.

Category 2, Floodway Area - The floodway area is the area in which no encroachment of man-made improvements should be permitted. No problems are likely to occur with light recreational use of such areas. However, in the case of heavy recreational activities or agricultural usage, all structures would have to be kept out of the floodway and, in addition, any grading would have to be controlled rigidly. Essentially, the problems would be similar to those in Category 1, but less severe.

Categories 3 and 4, 100-Year Flood Plain - These two categories refer to the flood plain (outside of the floodway area) as it presently exists and as it will exist in the future with further flood control improvements. Raising of the land surfaces above the flood level by grading, or protection from floods by levees would be acceptable, but the development costs obviously would be greater than for lands outside of the flood plain.

Santa Barbara County
Flood Hazard

- Stream Channel or Channel Protection Reserve Area
- Floodway Area
- 100-Year Flood Plain (Combines Categories 3 and 4)
- Standard Project or 500-Year Flood Plain (Combines Categories 5 and 9)
- Unknown Flood Hazard Area
- Local Drainage Problem Area (Combines Categories 6, 7 and 11)
- Area With No Flood Hazard

GUADALUPE
SANTA MARIA
ORCUTT
CASMALIA
HARRISTON
LOS ALAMOS
VANDENBERG AIR FORCE BASE
LOS PADRES NATIONAL FOREST
Zaca Lake
SISQUOC
CUYAMA
BUELLTON
SOLVANG
SANTA YNEZ
SANTA YNEZ RIVER
GAVIOTA
POINT CONCEPTION
SANTA BARBARA
SUMMERLAND
SAN LUIS OBISPO COUNTY
KERN COUNTY
VENTURA COUNTY
Twitchell Reservoir
State Route 166
State Route 154
N
FLOOD HAZARD

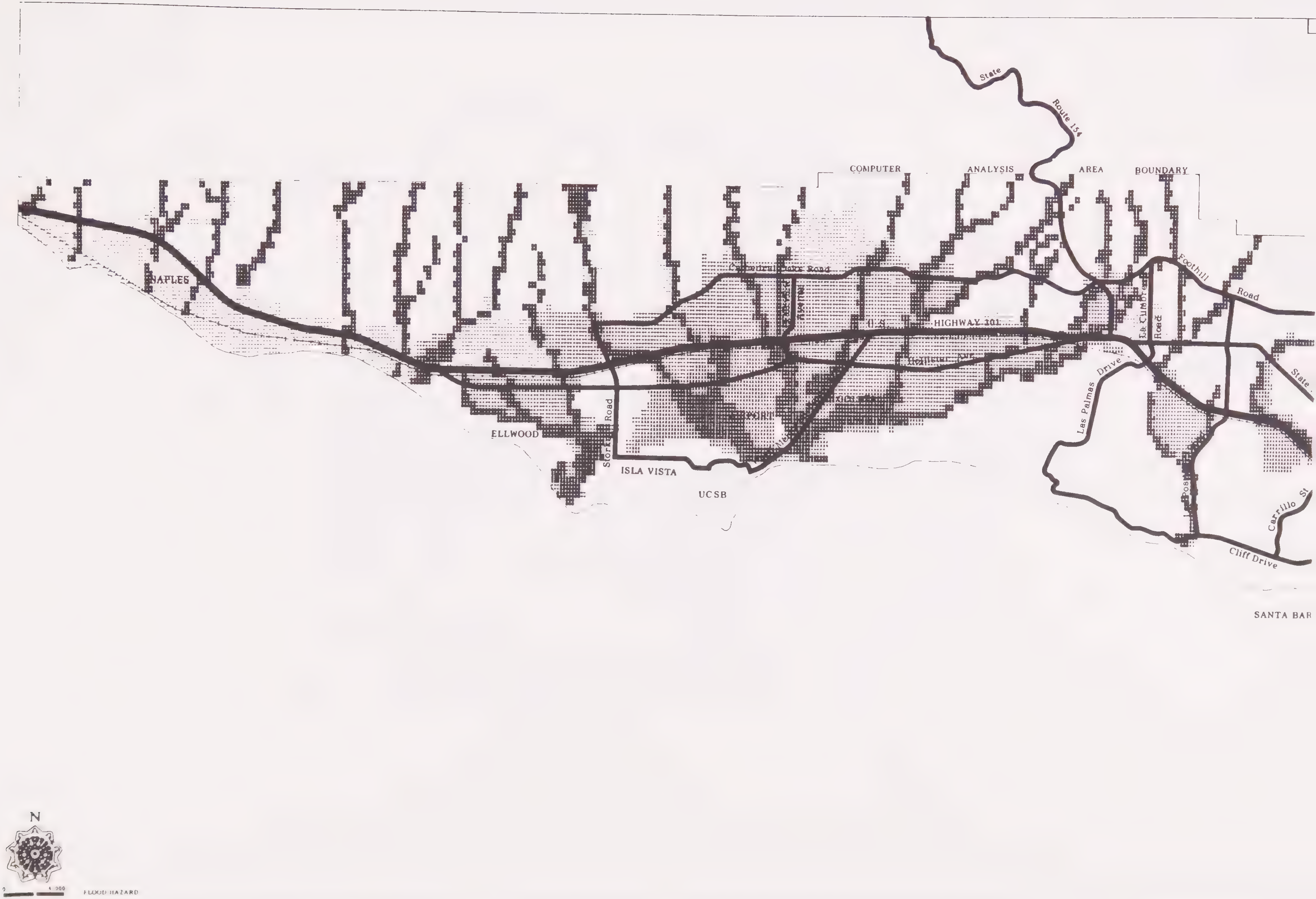
South Coast Study Area ~ West
Flood Hazard

- Stream Channel or Channel Protection Reserve Area
- Floodway Area
- 100-Year Flood Plain (Combines Categories 3 and 4)
- Standard Project or 500-Year Flood Plain (Combines Categories 5 and 9)
- Unknown Flood Hazard Area
- Local Drainage Problem Area (Combines Categories 6, 7 and 11)
- Area With No Flood Hazard


LOS PADRES NATIONAL FOREST
STUDY AREA BOUNDARY
SANTA BARBARA COUNTY
Canyon Road
Road
State Street
Anapamu St
Milpas Street
MONTECITO
SUMMERLAND
Carrillo St
SANTA BARBARA
Road
Road
Rincon Rd
N

South Coast Study Area~East
Flood Hazard

- Stream Channel or Channel Protection Reserve Area
- Floodway Area
- 100-Year Flood Plain (Combines Categories 3 and 4)
- Standard Project or 500-Year Flood Plain (Combines Categories 5 and 9)
- Unknown Flood Hazard Area
- Local Drainage Problem Area (Combines Categories 6; 7 and 11)
- Area With No Flood Hazard



FLOOD HAZARD

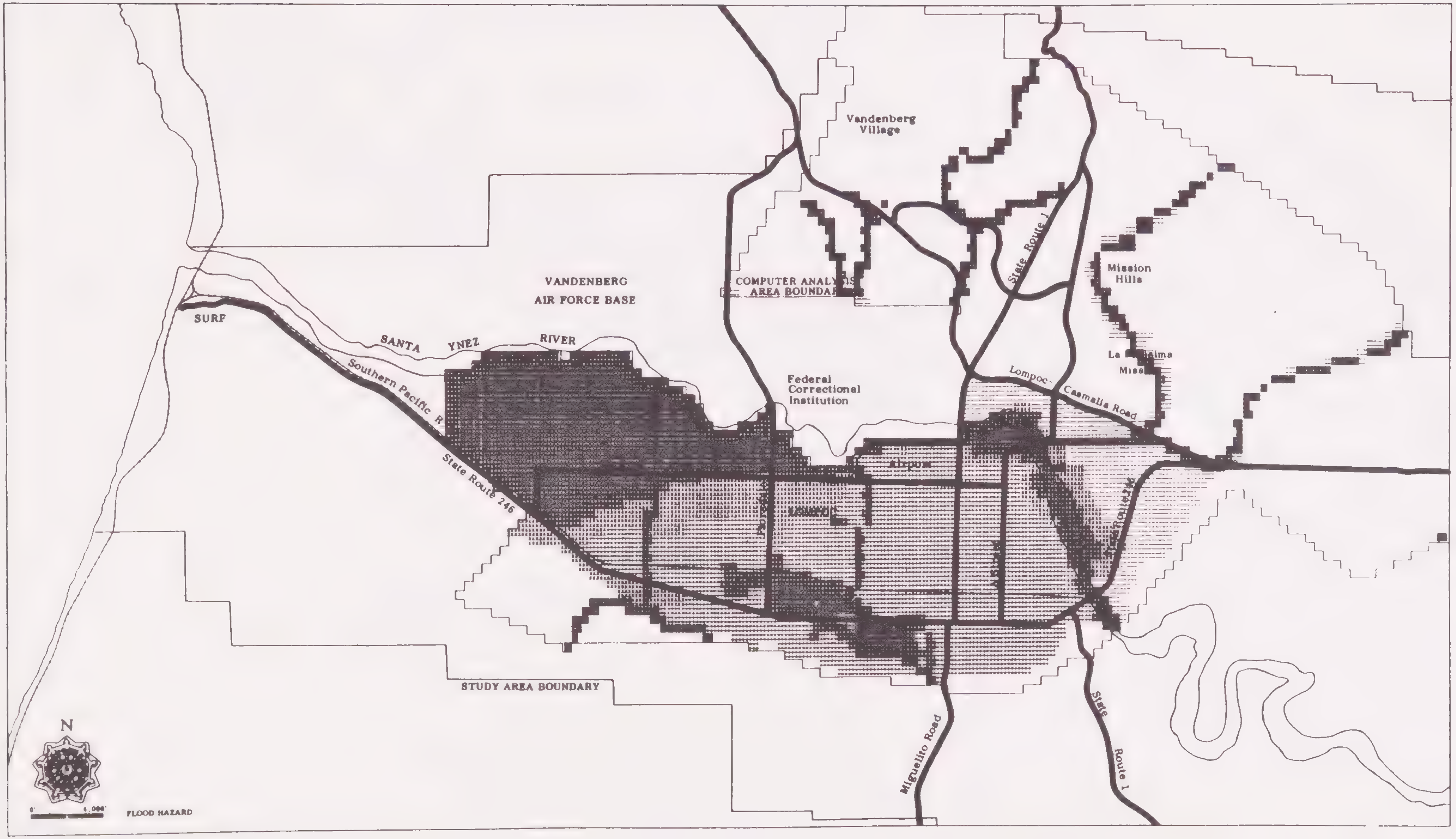
Santa Ynez Valley Study Area
Flood Hazard

	Stream Channel or Channel Protection Reserve Area
	Floodway Area
	100-Year Flood Plain (Combines Categories 3 and 4)
	Standard Project or 500-Year Flood Plain (Combines Categories 5 and 9)
	Unknown Flood Hazard Area
	Local Drainage Problem Area (Combines Categories 6, 7 and 11)
	Area With No Flood Hazard


COMPUTER ANALYSIS AREA BOUNDARY
LOS OLIVOS
HIGHWAY 101
STUDY AREA BOUNDARY
BALLARD
Base Line Avenue
State Route 154
Refugio Road
SANTA YNEZ
State Route 246
BUELLTON
SOLVANG
Airport
SANTA YNEZ RIVER
Alisal Road
N
0
4 000
FLOOD HAZARD

Lompoc Study Area
Flood Hazard

- Stream Channel or Channel Protection Reserve Area
- Floodway Area
- 100-Year Flood Plain (Combines Categories 3 and 4)
- Standard Project or 500-Year Flood Plain (Combines Categories 5 and 9)
- Unknown Flood Hazard Area
- Area With No Flood Hazard



Vandenberg
Village
VANDENBERG
AIR FORCE BASE
COMPUTER ANALYSIS
AREA BOUNDARY
State Route 1
Mission
Hills
SURF
SANTA YNEZ RIVER
Southern Pacific R
Federal
Correctional
Institution
Lompoc-Casmalia Road
State Route 246
STUDY AREA BOUNDARY
N
Miguelito Road
State Route 1
FLOOD HAZARD

Santa Maria-Orcutt Study Area
Flood Hazard

Stream Channel or Channel Protection Reserve Area

Floodway Area

Unknown Flood Hazard Area

Local Drainage Problem Area (Combines Categories 6, 7 and 11)

Area With No Flood Hazard

SAN LUIS OBISPO COUNTY
GUADALUPE
State Route 166
SANTA MARIA
COMPUTER
ANALYSIS
AREA
BOUNDARY
Stowell Road
Santa Maria Valley R. R.
STUDY AREA
BOUNDARY
Blosser Road
Black Road
Betteravia Road
BETTERAVIA
POINT SAL
Santa Maria
Airport
Route 1
State Route
135
U. S. HIGHWAY 101
Clark Avenue
VANDENBERG AIR FORCE BASE
ORCUTT
Southern Pacific R. R.
CASMALIA
N
FLOOD HAZARD

Category 5, Standard Project or 500-Year Flood Plain - This category includes lands that, although not in the 100-year flood plain area, conceivably could be inundated by a still larger flood. In this case it would appear that the degree of risk to improved recreational sites or agricultural uses would be so light as not to pose any particular problems. On the other hand, in the case of urban development, either some costs would have to be incurred to remove the lands from the flood plain or some small risk would have to be assumed for property damage in the event of a very rare large flood. Not only is the chance of inundation of lands in Category 5 small, but also the depth of such inundation probably would not be great. Accordingly, the degree of constraint on Category 5 lands for urban development is not major, although it does exist.

Categories 6 and 7, Local Drainage Problem Areas - These two categories cover the drainage problem areas that exist at present, and those that will exist in the future if proposed improvements are built. In general, the comments regarding Categories 3 and 4 also apply to Categories 6 and 7.

Category 8, No Flood Hazard - Lands in this category are not subject to development constraints caused by flood hazards.

Category 9, Areas Which May Be in 500-Year or Standard Project Flood Plain - The comments applying to Category 5 also apply to Category 9. However, the likelihood of problems is even more remote than it is in Category 5, because much of the land in Category 9 probably is not even within the 500-year or standard project flood plain.

Category 10, Unknown Flood Hazard - Areas in this category require more detailed study prior to development. Until such studies are made, Category 10 lands should be subject to the same restraints as Category 2.

Category 11, Unknown Drainage Hazard - Lands classified in Category 11 may have drainage problems, or may experience such problems in the future. Accordingly, in the absence of remedial actions or in the absence of technical findings demonstrating that no problem exists, the lands should be subject to the same restraints as Categories 6 and 7.

AREA ANALYSIS OF FLOOD HAZARDS

Outside of the four study areas, most of the lands are hilly or mountainous and consequently have been classified in Category 8, without potential flood hazard. In valley areas and along canyon bottoms some degree of flood hazard may exist. However, data generally are not available as to the degree of flood hazard or as to the areal extent of such lands. Accordingly, these valley floor and canyon bottoms outside of the urban study areas, the major portion of which are in the Cuyama Valley and along San Antonio Creek, have been shown

in Category 10, unknown flood hazard. More detailed studies could indicate that a substantial portion of these Category 10 lands are subject to no flood hazard or minimal flood hazard.

In the South Coast area, most of the mountainous lands fall in Category 8, no flood hazard, although canyon bottoms are shown as being in Category 10, unknown flood hazard. In the developed portion of the South Coast area, generally the coastal plain from Goleta easterly, most lands are in Category 8, no flood hazard, or Category 9, areas outside the 100-year flood plain which may or may not be within the 500-year or standard project flood plains. Most of the Category 9 lands in the South Coast area have been so classified because of lack of data on the limits of the 500-year or standard project flood plain. With additional study, these areas might be classified as having no flood problem.

Even within the developed portion of the South Coast area, there are lands subject to varying degrees of flood hazard. These lands generally lie in narrow strips along stream channels, although significant areas are subject to inundation near the Santa Barbara Airport in Goleta, in the low lying coastal portions of the City of Santa Barbara and in much of the Carpinteria area. However, completion of federal flood control projects would eliminate a significant portion of the flood hazard near Carpinteria and in the Goleta area. The Goleta flood control project would include improvement of the channels of Carneros, Tecolotito, San Pedro, Las Vegas, San Jose, Atascadero, and Maria Ignacia creeks. Those lands in the City of Santa Barbara lying below a 10 foot elevation are subject to flooding. Under a proposed joint program of the City of Santa Barbara and the County Flood Control District, drainage facilities to alleviate this problem would be constructed.

Most of the Santa Ynez Valley study area is in Category 8, no flood hazard. However, serious flood hazards do exist along the Santa Ynez River and along Alamo Pintado Creek. Flood hazards of unknown degree also may exist along other tributaries of the Santa Ynez River, and lands adjacent to these tributaries therefore are shown in Category 10. A large area of Alamo Pintado Creek and north of State Highway 150 has been classified in Category 11 because local drainage problems may develop in the future unless proper mitigating measures are taken during development of these lands.

In the Lompoc urban study area, the hillside areas surrounding the valley flood generally have no flood problems, except for lands adjacent to certain stream channels which may be subject to flood hazards of an unknown degree and, therefore, have been classified in Category 10. On the valley floor, a significant area is subject to inundation from the Santa Ynez River, including a flood plain which is up to one-half mile in width in the eastern end of the valley and which broadens out

to encompass a major portion of the western end of the valley. Even outside of the Santa Ynez River flood plain, the valley floor has been shown in Category 9 or Category 10 because of lack of data on possible flooding tributaries of the Santa Ynez. There are also possible localized flood problems in the southern portion of the Lompoc Plain resulting from runoff from La Salle Canyon, Sloans Canyon, and San Miguelito Creek. A federal project has been authorized to alleviate potential flooding adjacent to San Miguelito Creek. However, this program has not been funded, and there is no indication as to when it may be funded.

In the Santa Maria urban study area, flood hazards from the main stem of the Santa Maria River largely have been eliminated by water storage in Twitchell Reservoir and channelization of the river on the valley floor. Flood problems of unknown extent may exist in the southern end of the Santa Maria Valley, around Orcutt and Betteravia, resulting from runoff from the hills to the south. Most of the Santa Maria Valley is subject to potential local drainage problems which could occur if proper preventive measures were not taken prior to development of the lands. Drainage problems already exist at several locations in the valley, including some areas within the City of Santa Maria. The City currently is constructing additional storm drainage facilities to alleviate these problems on a staged basis.

CONCLUSIONS AND RECOMMENDATIONS

The County's and the cities' decisions on land use and development projects should be based on the following flood control considerations:

- In stream channels or floodway areas (Categories 1 and 2), no structures should be built, and any agricultural or recreational uses should be subject to controls so that the flood-carrying capacity of the stream is not impaired. However, utilizing more detailed engineering studies, applicants for development permission should be allowed to demonstrate to the satisfaction of the Flood Control Engineer that the boundaries of Category 1 or Category 2 areas should be adjusted.

- In the case of lands classified in Categories 3, 4, 6, 7, 10 or 11, areas which are or may be inundated by a 100-year flood, a prerequisite to permitting any construction should be either a demonstration that the site, in fact, will not be inundated by the 100-year flood, or a demonstration that such construction will be carried out in a manner that will protect the site from the 100-year flood. Governmental constraints on agricultural or recreational use of lands in the foregoing categories are unnecessary except where structures are involved.

- No controls over development of lands in Categories 5, 8, or 9, areas which are outside of the 100-year flood plain, are necessary.

- Adequate setbacks from flood channels should be required to provide access for operation and maintenance of the channels, to provide public access, to protect the stream channels and floodways from encroachment, and to create a buffer zone where bank erosion can be tolerated without threatening structures. The amount of such setback should be determined by the Flood Control engineer for each specific instance, and the lands in the setback should be publicly owned. A positive program for delineation and acquisition of these lands should be undertaken.

- Additional studies should be undertaken to define the proper classification of lands with respect to flood hazards in those areas where adequate data presently are not available.

- Flood plain zoning or other similar measures to prevent construction in high flood risk areas should be implemented.

- Where investigations indicate the desirability and feasibility of additional flood control works, these projects should be constructed as soon as possible.

RECOMMENDATIONS FOR FUTURE STUDY

The Seismic Safety and Safety Element attempts to investigate and evaluate in a general way all significant geologic, fire and flood problems. It also identifies subjects requiring investigation beyond the scope of this study because of the inadequacy of available information. Some of these are discussed below. It should be noted that tectonic seismic studies currently being made by the U.S. Geological Survey may provide useful data regarding some of these items, but these studies may also raise new questions.

Although investigations relative to development of specific sites will often provide useful information regarding the fundamental problems listed, overall studies of these problems should be made to provide broad guidance for effective planning and for building and safety control. This objective cannot be accomplished by relying solely on data from individual site investigations.

Some of the investigations recommended probably would involve significant expenditures, but the costs would be minor compared to the possible benefits. The amounts now being spent on seismic and geologic research are miniscule compared to past and potential future losses.

1. Basic Geologic Map Coverage

   The geologic maps of the County, which were used in this study, were based primarily on field work done in the 1930's and 1940's by T. W. Dibblee, Jr. (1950, 1966) and others (Woodring and Bramlette, 1950) of the U.S. Geological Survey. Although the quality of the work was good, the mapping was done at a different scale and to standards for different purposes than those needed currently for land use planning and development control. There are some significant geologic discrepancies at the boundaries of maps done at different times, even by the same investigator. These differences should be resolved and the work should be updated. In particular, more emphasis should be placed on mapping landslides, active faults (including the age of last movement), and other geologic hazards to be considered in land use planning. Subsequent to publication of the principal map sources utilized in the study, work in many local areas has been done by graduate students and consultants. These findings should be considered in preparing revised maps.

2. Index Map and Reference

In order to make the Bibliography of this report more useful, an index map should be compiled showing the areas covered by the various geologic reports and maps.

An up-to-date air-photo index showing air-photograph dates, scale, responsible agency, and coverage should be compiled. These data would be valuable to planners and to consultants in land planning, geologic, soil, and agricultural studies.

3. Possible Westerly Extension of the Big Pine Fault

Based largely on thesis work in progress by S. C. Comstock, a graduate student at the University of California at Santa Barbara, and an interpretation of ERTS-1 high altitude photos, we have postulated a westward extension of the Big Pine fault. This is considered a major active fault, and its extension would have a major effect on evaluating the seismicity of western Santa Barbara County. An investigation should be made to determine if the extension exists and if the fault is active as assumed. If not, a search should be made to locate the fault that caused the intense earthquakes of 1902 and 1915 in the area near and west of the town of Los Alamos. Remote sensing techniques or seismic survey lines across San Antonio Valley at several locations between Los Alamos and the coast might be helpful in locating the fault if it exists. The placement of a seismograph in the Vandenberg area and in the vicinity of Los Alamos should be considered. Precise level lines and small triangulation nets could be established to provide a base for future measurements.

4. Mesa Fault

Additional investigation of the Mesa fault is needed, particularly with respect to possible creep movement. This fault has been the subject of a study by Dr. Arthur Sylvester and graduate students at the University of California, Santa Barbara, and Mr. Phillip Olson, instructor of geology at Santa Barbara City College. Their continued work should be encouraged to more precisely locate the fault and determine its activity. In conjunction with these investigations, a study should also be made of the More Ranch fault, the western counterpart of the Mesa fault, to more precisely determine its location and seismic activity. Subsurface investigations, such as borings and trenching, instrumentation, and survey lines would be useful.

5. <u>Red Mountain Thrust Fault</u>

There is apparently some evidence of geologically recent movement of the Red Mountain thrust fault in Ventura County and concern that it may be the most dangerous fault in the South Coast area. It should be closely examined in the field in Santa Barbara County to determine if it should be reclassified from potentially active to active.

6. <u>Instrumentation</u>

An evaluation of the seismic history of Santa Barbara County has been handicapped by the lack of seismic records. A number of major earthquakes have occurred since the development of seismographs, but there is still a shortage of seismic instruments in critical areas of the County. More instrumentation is needed in addition to the present network of seismograph stations (8) established in the Santa Barbara area by the U. S. Geological Survey, Caltech, and the California Department of Water Resources (Figure 19). Survey methods used in the investigation of crustal movements in California (Greensfelder, 1972) should also be expanded and encouraged. We recommend that a study be made to determine the desirable location, number, type and distribution of additional instruments and survey methods in Santa Barbara County. Such a study should be coordinated with the various governmental agencies, universities, and individuals presently acquainted with and involved in this work.

In addition to the previously recommended seismograph stations at Vandenberg and Los Alamos, seismographs in the Cuyama Valley and in the area of the intersection of the Big Pine and Nacimiento faults would be valuable. Lee and Vedder (1973) have also indicated a "few ocean-bottom seismographs placed in the middle of the channel would greatly improve the ability to locate earthquakes with precision."

7. <u>Liquefaction and Collapsible Soils</u>

Although we are not aware of any historic evidence of liquefaction in Santa Barbara County, fundamental data regarding groundwater level and soil characteristics necessary to make such an evaluation are generally lacking. Certain lowland areas with apparent high groundwater levels should be investigated to determine the real potential for liquefaction. Areas suggested for special study are Carpinteria slough, Santa Barbara Harbor area, Goleta slough, Cuyama, and the large alluvial areas in the Santa Ynez, Lompoc, and Santa Maria Valleys.

Collapsible soil problems have been reported in certain areas of the Cuyama Valley. Although not one of the urban stuay areas, possible future development in this area would justify a study of collapsible soils.

8. Sand and Gravel Deposits

Sand and gravel deposits are very important to the construction industry and the future development of Santa Barbara County. Such deposits should be conserved, and at the same time consideration should be given to the possible detrimental effects of their removal from stream channels. Since sand and gravel pits are almost invariably located in the alluvial deposits of major channels, removal of these materials reduces the amount of sediment deposited at the mouths of major rivers. This reduction in the sediment supply for wave transport down the coastline presumably means that the waves are "under-nourished" and have a greater tendency to pick up sand, thus increasing coastline erosion. An associated problem is the degradation of river channels above the point of removal. This is a complex problem deserving investigation well beyond the scope of this study.

9. Inundation Maps

If active faults pass through a dam or reservoir, a potentially severe effect of fault movement would be failure of the dam and inundation of the land downstream. Considering the faults designated active or potentially active in this study, only one intersects a reservoir of significant size. The Santa Ynez fault crosses the Juncal dam area and impounded Jameson Lake. We have no specific information indicating the possibility of dam failure, but in view of the apparent lack of definite evidence to the contrary, we believe that it should be considered possible.

The function of inspecting and approving dams of a size large enough to be hazardous is the responsibility of the Division of Safety of Dams of the Department of Water Resources of the State of California. The following information was obtained from them. The dam, owned by the Montecito County Water District, actually consists of a main gravity dam and a separate subsidiary concrete multiple arch dam. The dam was constructed in 1930 based on a geologic report by Bailey Willis.

The Santa Ynez fault apparently passes through a narrow ridge in an east-west direction near the left abutment of the multiple arch (south side of the lake). From the data available, it is not clear how much consideration was given to the

possible seismic activity of the Santa Ynez fault and its effect on the proposed dam. An inspection report made during the heavy rains of early 1969 recommended additional study, but a comprehensive study apparently has not been made. An investigation of this problem is beyond the scope of this Seismic Safety Element , but it would appear that the matter deserves more study, and we would recommend that the State Department of Water Resources be encouraged to look more closely into the possible consequences on the dam in the event of movement on the Santa Ynez fault. In the interim, development should be restricted in the inundation area. Because the reservoir volume is not unusually large (6283 acre feet) and because the area downstream is essentially undeveloped, dam failure does not appear to be a major threat to developed areas. Consideration has apparently already been given to an emergency plan in the event of failure and this should probably be reviewed.

The Santa Barbara County Flood Control District presently has Inundation Maps as required by the Office of Emergency Services for Juncal and Gibralter Dams. Inundation Maps for Twitchell and Bradbury Dams are not yet available. However, the Flood Control District has prepared a report entitled "Emergency Procedures for the Santa Ynez River Flood Plain" which describes the potential downstream flooding as a result of the collapse of Bradbury Dam.

10. Coastal Zone

A report entitled "Geology" with supplemental policies and findings has been prepared by the South Central Regional Commission (April 18, 1974) with various recommendations and guidelines for development on coastal bluffs with respect to geologic hazards. However, a more detailed study should be undertaken in a narrow zone along the coast to delineate specific geologic problems or hazard areas. At the map scale used for this Seismic Safety study, this zone is not much wider than a pencil line, but is quite important because of potential bluff instability, beach erosion, and tsunamis protection. In particular, such a study should delineate the areas where the absence of a sea cliff provides no tsunami protection to inland development.

11. Up-date of the Seismic Safety and Safety Element

We recommend that the Seismic Safety/Safety Element be up-dated in approximately three years. By that time, many construc-

tive comments on the present study and much additional technical information should be available. In particular, new information on fault location and recurrence intervals from studies now in progress by U.S. Geological Survey should be available. The additional soil and geologic data obtained over the intervening period could be utilized to modify the various problem ratings and redefine mapped boundaries. The Geologic Problem Index should be applied at a more detailed scale in areas of particular concern; i.e., Los Alamos, New Cuyama, Coastal Zone.

The Seismic Safety and Safety Element up-date should include an analysis of hazardous land use relationships with particular regarc to hazards from the transportation, storage and use of fuels and other dangerous chemicals and explosives. As part of this study, an inventory of existing structures should be performed to determine their physical condition and location relative to potential fire, flood, geologic and hazardous land use safety problems. Additionally, the up-date should recognize hazards related to public protection and supply of emergency services in remote areas of the County, and define the roles of the various public safety agencies in an overall safety program.

Information on the Alisal Lake and dam should be added to this element once it becomes available from the completed environmental document for the proposed development on Alisal Ranch.

VIII. Appendix

GLOSSARY

The following are definitions of selected geological and seismological terms commonly used in practice and in this report. The meanings are intended as general definitions. Geological terms not in the glossary can be found in a standard dictionary or in the Glossary of Geology (American Geological Institute, 1973).

<u>Acceleration</u>: The time rate of change of velocity. In association with seismicity and ground motion, it is generally expressed in terms of the acceleration of gravity, "g" (32.2 feet per second per second), e.g., a ground acceleration of 0.2g.

<u>Accelerogram</u>: A graphic record depicting the time history of ground acceleration during a seismic event.

<u>Alluvium</u>: Unconsolidated gravel, sand, and finer sediments deposited principally by running water.

<u>Amplification</u>: The increase in earthquake ground motion that may occur to the principal components of seismic waves as they enter and pass through different earth materials.

<u>Amplitude</u>: The extent of an oscillation or a vibratory movement. On graphic recording, it is the distance from the zero datum to the crest of the plot.

<u>Anticline</u>: A fold, the core of which contains the stratigraphically older rocks; it is convex upward.

<u>Attenuation</u>: The decrease in earthquake ground motion (acceleration, velocity, etc.) that may occur as the seismic waves travel away from the energy source or as they enter and pass through different earth materials.

<u>Bedrock</u>: Consolidated, undisturbed rock material of any sort, in place either at surface or beneath surficial soil deposits.

<u>Collapsible Soil</u>: Soils which exhibit sudden settlement due to load application and introduction of water. Generally loose deposits with particles cemented by soluble materials or clay. Wetting can destroy interparticle cementation with a resulting collapse of the soil structure.

Compaction: The densification of a sediment by means of a mechanical manipulation.

Creep: Gravitational creep is the slow downslope movement of soil or other surficial material.

Damping: A resistance to vibration that causes a progressive reduction of motion with time or distance.

Duration: Interval of time (seconds) in which significant strong ground shaking occurs during an earthquake. Usually the time interval between first and last acceleration peaks above some defined acceleration value (e.g. greater than 0.5g or 25-30% of maximum acceleration).

Epicenter: That point on the earth's surface directly above the point of origin (focus) of an earthquake.

Expansive Soil: Generally cohesive or fine-grained soils which increase (decrease) in volume as a result of water absorbtion (reduction) in the soil structure.

Fanglomerate: Consolidated deposits of an alluvial fan; a variety of conglomerate which is coarse, moderate to well graded and contains angular to rounded rocks.

Frequency: The number of repetitions of a periodic process in a unit of time.

Frequency of Vibration - Number of complete waves which pass a given point per second (cycles per second).

Frequency of Occurence - Number of seismic events (earthquakes) occurring in a given time.

Fault: A fracture or fracture zone in the earth's crust along which failure has occurred in response to the accumulation of stress in the rocks and the materials on opposite sides have been displaced relative to one another parallel to the fracture. The displacement may range from a few inches to many miles.

Historically Active Faults are those on which destructive earthquakes have occurred within historic times and which are reasonably well documented.

Active Faults are those that show evidence of displacement or activity during the most recent epoch of geologic time (Holocene - last 11,000 years).

Potentially Active Faults are those which displace deposits of late Pleistocene age (11,000 to 500,000 years) and show no evidence of Holocene (0-11,000 years) movement.

Inactive Faults are those that only displace rocks of early Pleistocene Age or older (500,000 years or older) and show no signs of more recent movement.

Fault Creep: Apparently continuous displacement along a fault at a slow but varying rate, usually not accompanied by felt earthquakes (see also tectonic creep). Fault creep is not necessarily tectonic in origin; it may result from artificial withdrawal of fluids or solids.

Fault Displacement: Relative movement of the two sides of fault, measured in any specified direction.

Normal Fault - A vertical to steeply inclined fault along which the block above the fault has moved downward relative to the block below; also includes vertical faults with vertical slip.

Reverse Fault - A steeply to slightly inclined fault in which the block above the fault has moved upward relative to the block below the fault (Thrust Fault).

Left-lateral Fault - A fault on which relative movement is generally horizontal and in which the block across the fault from the observer has moved to the left.

Right-lateral Fault - A fault on which relative movement is generally horizontal and in which the block across the fault from the observer has moved to the right.

Strike-slip Fault - A fault in which the movement is principally horizontal and is appromately in the direction of the strike of the fault.

Fault Sag: A narrow tectonic depression common in strike-slip fault zones. Fault sags are generally closed depression less than a few hundred feet wide and approximately parallel to the fault zone; those that contain water are called sag ponds.

Fault Scarp: A cliff or relatively steep slope formed by displacement of the ground surface along a fault.

Fault Trace: The line of intersection of a fault plane with the earth's surface.

Focus: That point within the earth which is the center of an earthquake and the origin of its elastic waves (Hypocenter).

Fold: A curve or bend of rock strata resulting from deformation in the earth's crust.

Formation: A geological formation is a rock unit of distinctive characteristics which formed over a limited span of time and under generally uniform conditions. A rock body of some considerable areal extent which can be recognized, named, and mapped.

Fracture: A general term for discontinuities in rock, includes faults, joints, and other breaks.

Fundamental Period: The longest period (duration in time of one full cycle of oscillatory motion) for which a structure or soil column shows a response peak - commonly the period of maximum response.

Graben: A fault block, generally long and narrow, that has been dropped down relative to the adjacent blocks by movement along the bounding faults.

Ground Failures: Include mudslide, landslide, liquefaction, subsidence.

Ground Lurching: Surface cracking or distortion due to motions of the ground during an earthquake. Not necessarily directly connected to a fault plane.

Ground Rupture: Lateral or vertical displacements along a fault plane in the upper few feet of soil or rock due to movement on that fault plane.

Ground Shaking: Motions of the soil or rock during an earthquake. May or may not result in rupture, lurching or other ground failure.

Ground Water: In a broad sense, all free water located below the ground surface, including perched and static water levels.

Holocene: Geologic age, equivalent to Recent Epoch (0-11,000 years).

Hypocenter: That point along a fault within the earth where rupture begins and from which earthquake waves originate. (Focus)

Intensity: A subjective measure of the force or size of an earthquake at a particular place as determined by its effects on persons, structures, and earth materials. The principal scale used in the United States today is the Modified Mercalli Intensity Scale.

Landslide: The downward and outward movement of slope-forming materials, such as rock, soil, artificial fill, or combinations of these materials; the topographic feature and the deposit resulting from such movement.

Liquefaction: The sudden loss of strength and decrease of the shearing resistance of a saturated cohesionless soil resulting from high water pressure between soil grains produced by intense ground shaking. This loss of strength leads to a "quicksand" condition in which objects can either sink or float depending on their density.

Magnitude: A measure of the strength of an earthquake or the strain energy released by the earthquake as determined by measuring the amplitudes produced on standardized recording instruments (seismograph).

Microearthquake: An earthquake having a magnitude of 2 or less on the Richter scale.

Microseismic Event: Earthquake or man-induced vibrations observable only with instruments.

Modified Mercalli Scale: (See Intensity).

Period: The time necessary to complete one cycle of a cyclic function.

Plastic Deformation: A permanent change, excluding rupture, in the shape of a solid.

Pleistocene: An epoch within the Cenozoic Era of the geologic time scale, usually taken to cover the last two million years.

Predominant Period: The period at which the spectral acceleration reaches a maximum.

Remote Sensing: The acquisition of information or measurement of some property of an object by a recording device that is not in physical or intimate contact with the object under study. The technique employs such devices as the camera, lasers, infrared and ultraviolet detectors, microwave and radio frequency receivers, and radar systems.

Response Spectrum: A graphical tool of structural dynamic analysis relating the response of a structure (in the forms of deflections, velocities and accelerations) to ground motions (including those resulting from an earthquake).

Richter Scale: A scale of earthquake magnitude based on the logarithm (base 10) of the amplitudes of the deflections created by earthquake waves and records by a seismograph.

Sag Pond: Enclosed depression, generally occupied by water, formed when movement along a fault has disturbed the surface or subsurface continuity of drainage.

Sand Ridges, Boils, Volcanoes: Low ridges or accumulations of sand resulting from increased groundwater pressures where saturated cohesionless materials are compacted by earthquake ground vibrations.

Seiche: Wave generated in a lake, reservoir or pond by an earthquake or landslide. Periodic oscillation of a body of water.

Seismic: Pertaining or related to an earthquake or earth vibration, including those that are artificially induced.

Seismograph: An instrument that scribes a permanent continuous record of earth vibrations.

Seismometer: A device that detects vibrations of the earth, and whose physical constants are known sufficiently for calibration to permit calculation of actual ground motion from the seismograph.

Shear: A mode of failure whereby two adjacent parts of a solid slide past one another parallel to the plane of failure.

Shear Wave: A distortional, secondary or transverse wave.

Strain: Deformation in the dimensions or shape of a body resulting from applied stress. The change in length per unit of length in a given direction.

Stress: In a solid, the force per unit area, acting on any designated plane within it.

Strong Motion: Ground motion produced by a "strong" earthquake or one capable of producing damage to structures. The magnitude of such an earthquake may vary considerably according to the character of the earthquake.

Subsidence: A local mass movement that involves mainly the gradual downward settling or sinking of the solid earth's surface with little or no horizontal motion.

Syncline: A fold, the core of which contains the stratigraphically younger rocks; it is concave upward.

Tectonic: Of, pertaining to, or designating the rock structure and external forms resulting from deep-seated crustal and subcrustal forces in the earth. Pressures causing such deformations often result in earthquakes.

Tectonic Creep: Slow, apparently continuous movement along a fault, resulting from deformation of the earth's crust as opposed to an earthquake in which movement is relatively rapid; also called slippage.

Tectonic Stress: Stress caused in rock structures as a result of deformation of the earth's crust.

Tsunami: Sea wave generated by a submarine earthquake, landslide or volcanic action. Commonly referred to as tidal waves or seismic sea wave.

Water Table: The level beneath the ground surface below which all openings in rocks or sediments are filled with water.

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